Mobile Television Services Feasibility Study for Thailand

Project on Development of a Roadmap for Mobile Television Broadcasting Deployment and Regulation in Thailand

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May 2015

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Content

Introduction

By virtue of Section 27 and Section 49 of the Act on Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services B.E. 2553 (2010), the NBTC has formulated the Broadcasting Master Plan for the period 2012 – 2016 (BMP).

In the BMP the NBTC has formulated its general mission and objectives, as well as specific strategies for digital terrestrial television broadcasting (DTTB) and digital sound broadcasting (DSB). Mobile television services, based on a digital terrestrial broadcasting (either audio or video) network, are considered to be a subset of DTTB or DSB services and are referred to as MTV services (by the ITU). The BMP does not explicitly mentioned MTV services. However from the wording of the BMP it may be concluded that MTV services were not intended to be included.

But as MTV services are (continuously) discussed and also presented to the NBTC by (foreign) industry parties as useful services for the Thai people, the NBTC has to define its policy and objectives around a possible introduction of these services in Thailand.

The ITU and NBTC agreed a project document (as an Annex to the Voluntary Contribution Agreement) specifying the project scope, objectives and expected results and a provisional timeline for carrying out a feasibility study, as well as defining a strategy for a possible introduction of MTV services.

This report includes the results of the feasibility study carried out in the period from September 2014 till May 2015. The objective of the study is to assess whether an introduction of MTV services is feasible in technical and economic terms. If deemed feasible, the study should also define the conditions under which such an introduction would be feasible. For this study extensive desk research was carried, country study visits to Japan and South Korea, as well as a set of interviews with relevant industry parties in Thailand.

This report is structured as follows:

1. Defining mobile television services;
2. Mobile television systems;
3. MTV and LTE implementation aspects;
4. Current Thai TV & Mobile Market;
5. Demand for Mobile VOD & Linear TV;
6. Future scenarios;
7. Spectrum Management and Regulations;
8. Conclusions and recommendations;

Annex A: ISDB-T;
Annex B: ATSC-M/H;
Annex C: T-DMB;
Annex D: LTE-A system improvements;
Annex E: Detailed coverage maps for in-car reception.

1. Defining mobile television services

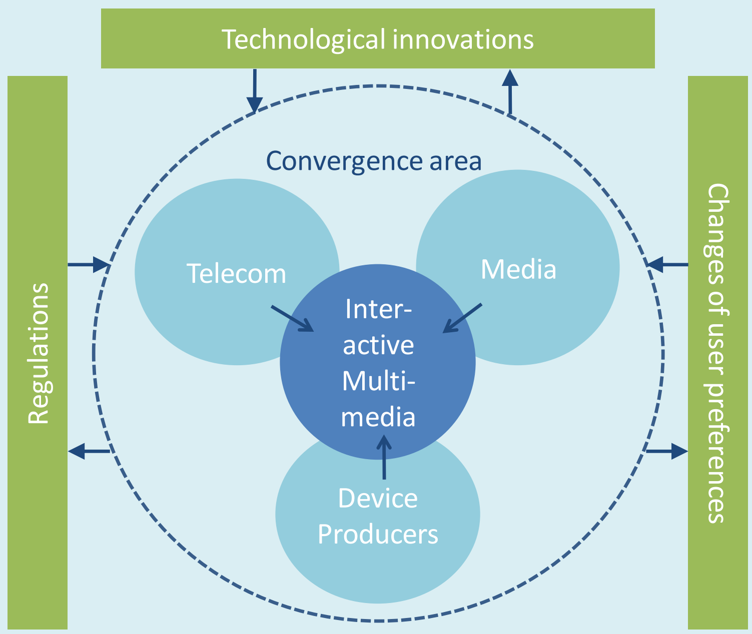
A feasibility of mobile television services in Thailand cannot be carried out without considering global developments and convergence trends observed. Also the mobile television services should be further categorized and defined to better understand the various services, receivers and technologies available globally as well as in Thailand.

This Chapter is structured as follows:

1. Convergence trends;
2. Categorizing services;
3. User environments and receivers;
4. Defining mobile television services.

1.1 Convergence trends

Convergence is the process whereby industries, services and devices are merged into a single market place. This process is driven by three external factors as illustrated in Figure 1.



Source: Convergence Consulting Company

FIGURE 1: CONVERGENCE AREA AND KEY DRIVERS

As Figure 1 suggests market trends can largely be explained by changes in consumer preferences, technological innovations and regulatory changes. It also shows that the middle of the converged market place is comprised by interactive multimedia services. These services include a wide range of services. Mobile television services are the mobile part of the converged market place. The next Section explains the different categories of interactive multimedia services and how mobile television services are part of this group of services.

1.2 Categorizing services

The scope of interactive multimedia services includes many different services, applications and technologies and a categorization is needed to understand differences.

From a service perspective (i.e. the service offered to the end-user) interactive multimedia services can be split into two basic forms:

1. Linear services: the service provider schedules the audio-visual content, plays-out and distributes the audio-visual content accordingly. Linear services are mostly distributed on the basis of 24 hours a day and 7 days a week (24/7). The most widely known example is linear television services from Public Service Broadcasters (PSB) and commercial broadcasters. This category also includes TV services whereby the end-user can temporarily pause and restart the broadcast or can restart the beginning of the broadcast. With this type of 'delay' or 'catch-up' features the essence of scheduled play-out remains unchanged. These features became possible with Personal Video Recorders (PVR) and also with PVR functionality sitting in the cloud (i.e. storage made available via the Internet) or broadcast network (e.g. IPTV network). Linear services can be offered free of charge[1] or on the basis of payment;
2. Non-linear services: the end-user determines what audio-visual content (often from a structured content library) and when this content is to be played out. A commonly known service in this category is Video on Demand (VOD)[2]. VOD like services are often paid services and providers can dice and slice the video content in many difference ways and apply different payment arrangements (e.g. Pay per View –PPV or periodical subscriptions) but they leave the end-user in command for scheduling the audio-visual content. These non-linear services also include time shifting the content. Time shifting is intended to view the content at a moment at the viewer's convenience. It can include pausing and rewinding linear television services (i.e. live television) as well as playback of the content after the initial broadcast.

The above services categories can be offered in many commercial arrangements and they don't differ in this aspect. However they may differ in how service availability and picture quality are managed by the provider of the interactive multimedia service. It is important to note that we focus here on the service levels of the audio-visual or video service. Two basic forms can be distinguished:

[1] A well-known form is Free-To-Air (FTA) television services. It should be noted that FTA refers to the content provider or broadcaster not charging the end-user directly. They finance their business on the basis of advertising income and/or license fees. However the network operator may charge the end-users for receiving a bouquet of FTA services.

[2] Near Video on Demand services whereby the content is played out in a carrousel (e.g. the film starts every 15 minutes) can be considered as a linear service. Such services are possible on traditional one way broadcast networks.

1. Video services with managed Quality of Service[3] (QoS): in this category the service provider sets, manage and offers end-users (minimum) picture quality and service availability levels. The classic example is a PSB that distributes its television service over its own terrestrial broadcast network. However it is also possible that the service/content provider distributes over third party networks. The service/content provider agrees the (minimum) service levels with the network operator in a distribution agreement or contract. Such a contract may include guaranteed service levels whereby a form of financial compensation is agreed in case of underperformance;
2. Video services with unmanaged QoS: the service/content provider does not set/manage service levels and consequently does not offer any to end-users. An example that falls in this category is content providers offering their audio-visual content over the Internet (i.e. OTT). The Internet Service Provider (ISP) or mobile network operator offering the Internet access to the end-user does manage service levels. However the ISP or mobile operator does not actively manage picture quality and service availability specifically for the individual service/content provider.

The last dimension for categorizing interactive multimedia services is the technical platform carrying these services. There are two basic forms:

1. Traditional broadcast networks: these networks are specifically designed and deployed for distributing audio-visual services. They are based on international transmission standards (such as ATSC, DVB, ISDB and DMB) and are essentially one-way networks. They can offer a semi-interactive component by broadcasting content in carousels (for example Teletext). They can be wired and wireless, including respectively coax cable networks and satellite, terrestrial and mobile networks;
2. IP-based networks: these networks route traffic (i.e. data) over routers to addressable end-user equipment. These networks are two-way (i.e. duplex) and switched networks whereby traffic is managed by IP protocols. The data can represent audio-visual services. They include networks like HFC and IPTV networks but also the Internet as offered by ISPs. Again they can also be wireless like third and fourth generation (3G/4G) mobile networks (based on international standards like UMTS and LTE).

These platforms come with different end-user equipment (or one could say with different network terminating equipment). The traditional broadcast networks require transmission standard compliant receivers such as Set Top Boxes (STB) or handsets. For IP-based networks the range of end-user equipment is much wider and range from smart phones, tablets, phablets, laptop/desktop computers and game consoles. However receivers from both platforms can be integrated into one single device, combining broadcast and IP functionality. The two most prominent examples are connected or smart television sets and mobile phones with ISDB-T/DMB-T receivers[4]. The HbbTV

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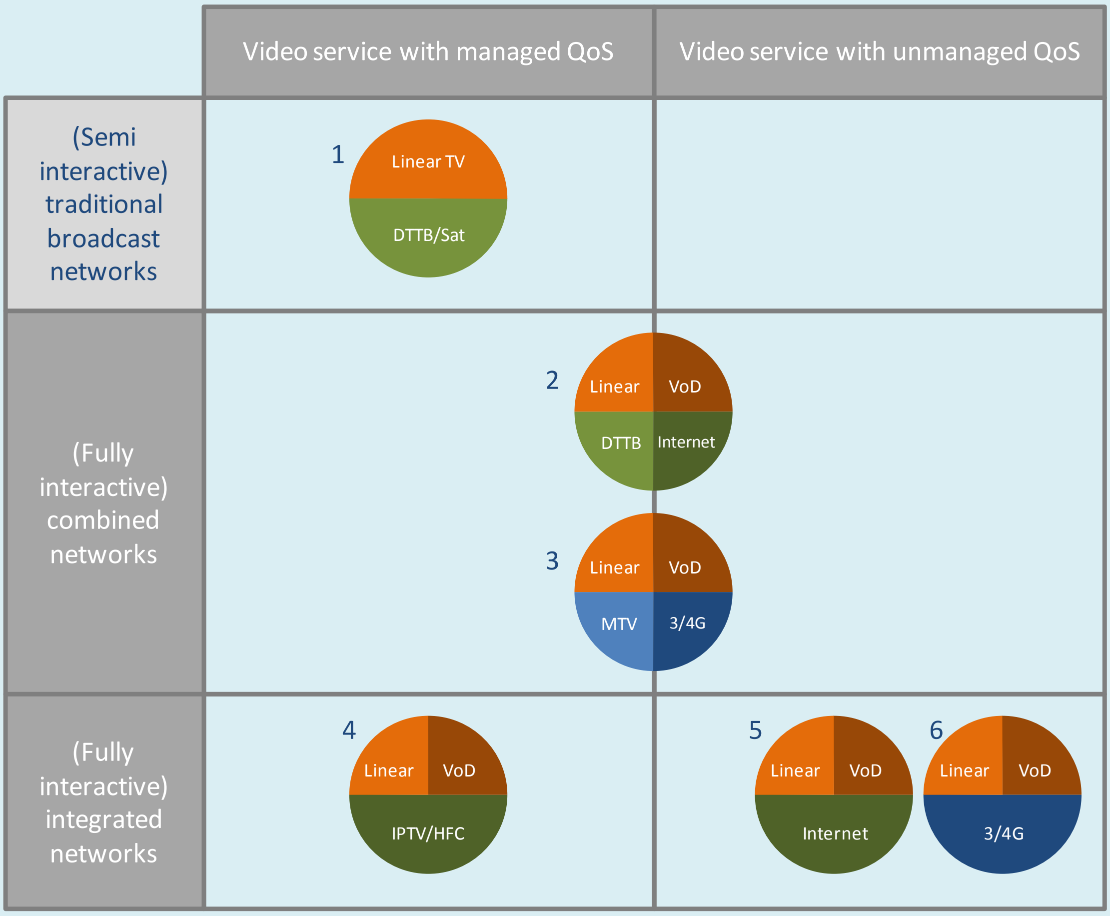
[3] The wider notion of Quality of Experience (QoE) is not used here as this includes many other aspects (like customer care, billing, etc.).

[4] ISDB-T and DMB-T enabled mobile phones are widely available in Japan and Korea respectively. DVB-H enabled mobile phones were available in Europe but services have been discontinued. However DVB-T2 Lite is

standard has been developed for connect television sets for integrating broadcast and internet services. The standard enables content/service providers to develop manufacturer independent applications for offering a seamless customer experience. Such a standard is (still) absent for mobile television services.

Figure 2 shows the different type of interactive multimedia services categorized along the three different dimensions. Please note that the platform dimensions comes back twice as network and device are interrelated; on the vertical axis of the grid and the bottom half of the circles. The top half includes the type of service; linear (TV) and non-linear (indicated with VOD).



Source: ITU

FIGURE 2: CATEGORIES OF INTERACTIVE MULTIMEDIA SERVICES

The scope of this feasibility report is on service categories 3 and 6 in Figure 2. For the Thai market the following market examples can be given for each of the categories:

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a newly developed standard for the purpose of offering MTV services (for example for mobile phones but also tablets).

1. Digital Terrestrial Television Broadcasting (DTTB) and Direct to Home (DTH) televisions services like offered by True Vision on their satellite platform. Interactivity is limited to data broadcasted in a carrousel, like the Electronic Program Guide (EPG) or text/information services;
2. DTTB and the 'Hollywood HDTV' service, all received with a connected television set (smart television set). The linear broadcast service is delivered over DTTB. The 'Hollywood HDTV' service is made available over the Internet and through a proprietary app on the connected television set;
3. **In scope of this feasibility study**. The MTV platform is not present in Thailand (yet). The 3/4G platform is present (see below);
4. True Vision's digital cable offering. Interactive services also include VOD services;
5. All services are offered over the Internet. The end user subscribes to Hollywood HDTV and watches linear TV from TV Thailand over any IP connected device (for example an Xbox or Apple TV box). Picture quality and availability is not guaranteed of any of the services;
6. **In scope of this feasibility study**. As service example 5 but the connected device is a 3/4G enabled smartphone. The linear and VOD service can be delivered by third parties (like TV-Thailand and Hollywood HDTV) or by the network operator like DTAC with the service 'Watchever'. It is important to note that in both cases picture quality of the linear TV services is not actively managed by the network operator[5].

1.3 User environments and receivers

In Section 1.2 the type of services were defined which are included in the scope of this feasibility study (categories 3 and 5). This section describes the environments in which end-consumers use these services as well as the type of receivers.

The following user environments can be identified for receiving linear and VOD services[6]:

1. Stationary – In this environment the user is within a non-public location that they use very regularly and have a high degree of control over, for example the home or an indoor work environment (office, workshop, etc.);
2. Nomadic– In this environment the user is in a public space that they use occasionally and have little control over, for example an airport, a train station or a shopping mall;
3. Mobile – In this environment the user is in a (fast) moving vehicle, in either the public or private domain (in cars, trains, boats, etc.).

Nowadays a wide range of (IP) connected devices are available, all able of delivering linear and VOD services. The following categories of devices can be listed:

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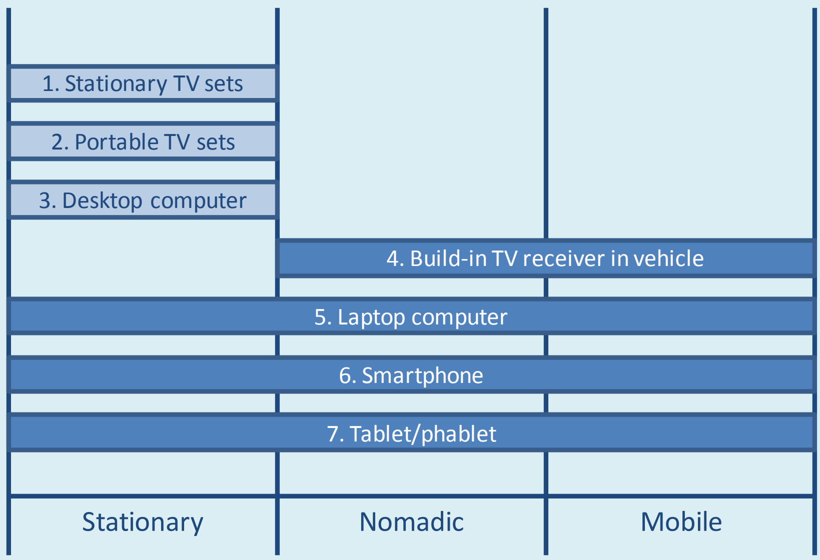
[5] For the VOD services the content is downloaded/streamed to the handset/connected device. The picture quality is determined by the compression technology (and file size) applied. Service availability (including blocking rate and download/streaming interrupts) are determined by the network topology and capacity management.

[6] Taken and adapted from EBU report TR 027 (Delivery of Broadcast Content over LTE Networks), July 2014.

1. Stationary television sets (including connected or smart television sets);
2. Portable television sets;
3. Desktop computers;
4. Build-in television receivers in motorized vehicles;
5. Portable/Laptop computers;
6. Smartphones;
7. Tablets/phablets.

From the above listed device types, the last three are considered handheld devices. Figure 3 shows the following every day and realistic combinations of the three user environments and different receiver types.



Source: ITU

FIGURE 3: COMBINATIONS OF USER ENVIRONMENTS AND RECEIVER TYPES

The combinations 4 to 7 in Figure 3 are in scope of this feasibility study.

1.4 Defining mobile television services

Following Sections 1.1 to 1.3 mobile television services can be defined and categorized in two main groups:

1. **MTV:** Linear television services (and possibly data[7]) delivered over a managed *broadcast* network whereby the picture quality is actively managed. It may have integrated interactive services, including VOD services, delivered over a switched (IP based) mobile network. The delivery of the MTV services is intended for reception on vehicle build-in and handheld devices in all user environments. The ITU refers to these services as MTV services.

2. **Mobile video services:** Linear television (and possibly data), VOD and interactive services delivered solely over a managed (IP based) *mobile* network whereby picture quality may be managed. The delivery of the mobile video services is intended for reception on handheld devices in all user environments.

The above definitions are working definitions which are used in this report to make an explicit difference as to avoid misunderstanding on what technology and services are addressed.

[7] Broadcasting data is also referred to as filecasting.

2. Mobile television systems

Following the working definition of mobile television services (see Section 1.4) this Chapter is split in two parts. The first part is addressing the available MTV systems and those which are relevant for Thailand. The second part is addressing the LTE system and its enhancements for providing mobile television services. LTE is a global standard and selection of available systems is not necessary.

This Chapter is structured accordingly:

1. MTV systems;
2. LTE system.

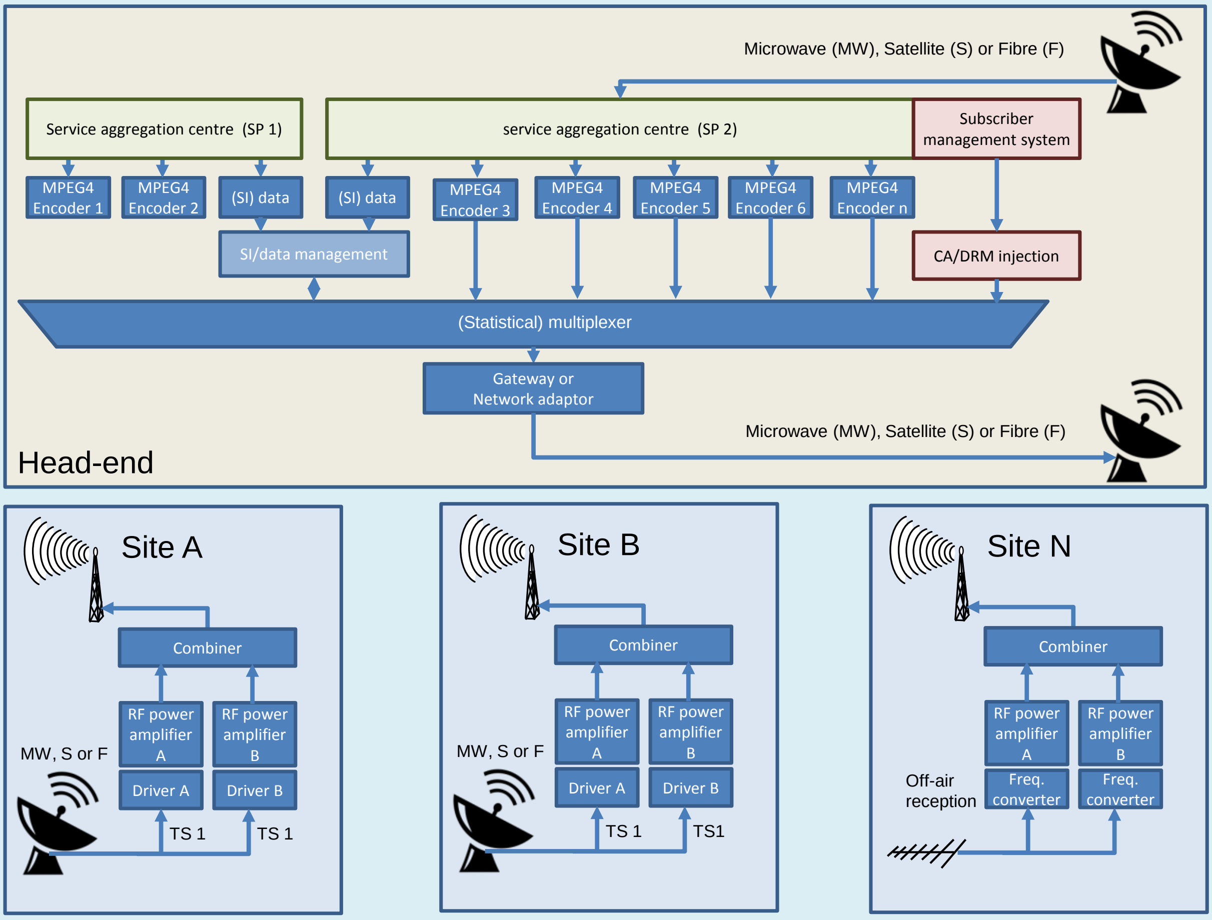
2.1 MTV systems

In the world various MTV systems have been developed, defined and standardized. In this Section first an overview will be provided of the architecture of MTV systems, followed by the available MTV systems as defined by the ITU. After having considered the available systems, this Section will also address which systems can be considered in Thailand as viable options. This Section will be concluded with a top-level system comparison between the selected MTV systems.

2.1.1 MTV system architecture

As explained in Section 1.4, MTV systems are based on broadcast networks and hence their system architecture is similar. They mainly differ for how services are encrypted and how interactive services are arranged for. The latter is an additional aspect of MTV systems which is absent in Digital Terrestrial Television Broadcasting (DTTB). As MTV services are generally delivered at hand-held devices with return path capabilities (for example through 3G or 4G networks), additional interactive information to the broadcast services can be provided. For example more background information on the broadcasted MTV services or the ordering of products, which could relate to the broadcasted MTV services.

Figure 4 shows a general network architecture, applicable to all MTV standards. Please note that in this example architecture two service providers (SP) deliver services at the head-end. One SP delivers encrypted (pay) services and the other Free-to-Air (FTA) services only. Also one of the sites (site N) is depicted as a site which is fed off-air (which is a typical broadcast functionality, absent in mobile networks).



Source: ITU

FIGURE 4: GENERAL NETWORK ARCHITECTURE FOR MTV SYSTEMS

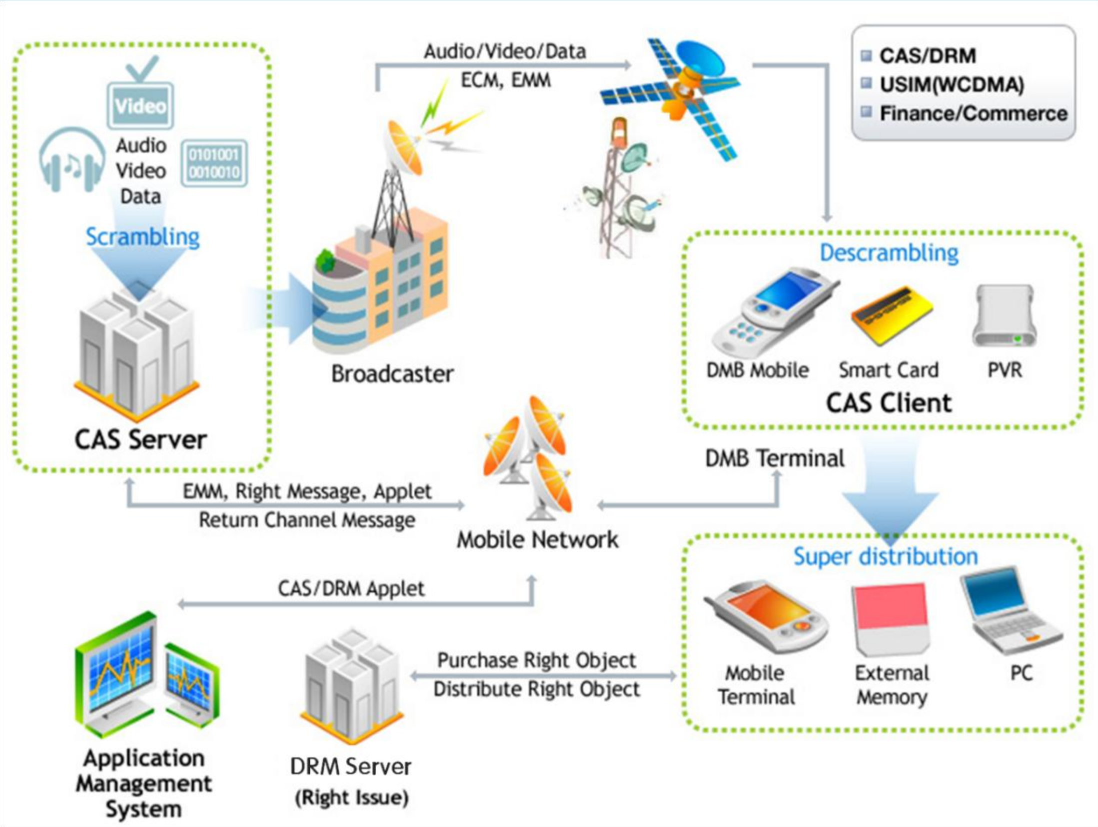
The implementation of encrypted MTV services and the provision of interactivity in MTV systems is standard dependent.

MTV encryption system

Encryption is generally applied to provide a conditional access for viewers that are entitled to receive a service and to prevent unauthorized use. Subscribing to a service can be the condition for acquiring access to pay services. Also citizenship of a country can be a condition for getting access in the situation where programme rights are geographically limited. In general, access is obtained by an encryption key. When a viewer fulfils the access conditions (i.e. possesses the right authentication) an authorization signal is transmitted to the service provider and the viewer can have access to the services. For this type of encryption system, the CAS (Conditional Access System) and DRM (Digital Rights Management) technologies are used.

It should be noted that the CAS is generally applied in the broadcast industry where as DRM is used in the telecommunications industry. A choice for a DRM system would imply that the subscriber management (and hence client ownership) is carried out by the mobile network operator (providing the interactive part of the MTV services). Hence the choice between CAS and DRM is a strategically important decision and will be dependent on the business model applied[8].

Figure 5 shows a general diagram of the CAS/DRM process for MTV broadcasting.



Source: ITU

FIGURE 5: DIAGRAM OF CAS AND DRM SYSTEMS

As depicted in Figure 5, the CAS/DRM process consists of the following steps:

1. Multimedia content is scrambled in the CAS server;
2. The scrambled signals are delivered to the client via the broadcasting network;
3. Also, an encrypted entitlement signal is transmitted to each receiver by using EMM (entitlement management message);
4. An encrypted CW (Control Word) is delivered to every receiver by using ECM (entitlement control message);
5. To get the CW, the receiver uses an IC card to crypt-analyse the ECM by using the key delivered by the EMM;

[8] As the ITU Guidelines on the transition from analogue to digital broadcasting (edition 2014) shows, various business models are possible when implementing and offering MTV services, see section 3.4.2.

6. Finally, the scrambled multimedia source, which is delivered through broadcasting network, is descrambled at the client's device.

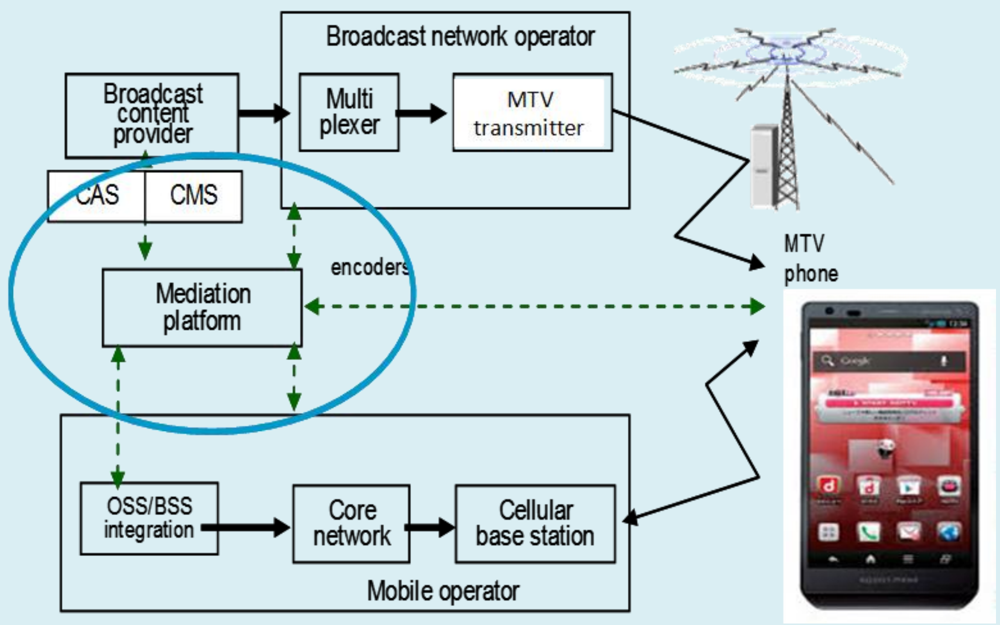
In the reverse direction, client requests and charging information are returned to the CAS operator through a telecommunication network (i.e. the interactive return-channel). All aspects on access rights of delivered content are controlled within the DRM system.

Selecting an encryption system is a trade-off between the cost of the system and the level of security required (the expected or reported chances of hacking the system). Since the required bit-rate for CAS/DRM (including SMS) depends on the number of subscribers (users) and the format used, designers have to reserve a suitable bit-rate for CAS/DRM in the total payload. On the other hand, it is essential that CAS/DRM technologies match with receiver processing technologies, so CAS/DRM designers have to cooperate with receiver manufacturers in the design of the CAS/DRM system. DRM systems are generally applied in the mobile industry and mobile operators have well established relationships with receiver manufacturers. Again this shows that the selection of the encrypting system is a strategic choice.

MTV interactive services

Standard functionality for service activation, billing and customer care and service deactivation takes special consideration when implementing an MTV system. Interactive services delivered over a mobile network require specific network integration work between the MTV and mobile system.

In markets where the mobile operator is the service provider (owning the client relationship), the MTV introduction should be integrated with existing service provisioning systems and organization. Special care and attention is needed for integrating the broadcast and mobile Operating Support Systems (OSS) for billing and customer care. For example, MTV services might be billed from the mobile operators billing system, requiring an interface from the MTV platform to the existing mobile platform. Also, MTV packages and services might be ordered with handhelds, requiring an interface from the mobile platform to the MTV platform. A 'mediation' platform is required for resolving these interface requirements. Figure 6 provides a schematic overview of such a mediation platform.



Source: ITU

FIGURE 6: MEDIATION PLATFORM FOR MTV AND MOBILE NETWORK INTEGRATION

The design and implementation of the mediation platform is very often a proprietary solution and tailor made to the specific OSS in place. It should also be noted that for this interactivity to work the mobile and MTV network should have the same service coverage areas. In the case of non-parallel service coverage areas, special attention is needed to inform the MTV users about service coverage. This information might change over time when network roll-outs are extended.

In markets where the MTV service is offered as a free-to-air offering, service activation, billing and service deactivation, is relatively simple[9]. Focus will be on the promotion of the MTV platform and informing the public about the availability of MTV equipped handsets. A mediation functionality is also not needed.

2.1.2 MTV system selection

Recommendation ITU-R BT.1833-3 (02/2014) covers eight standards for mobile (television) services delivered by digital broadcast networks (MTV) of which two are satellite systems and six are based on terrestrial networks. The terrestrial systems are referred to as Multimedia System A, B, C, F, H and T2[10]. Table 1 provides an overview of these systems. The table also includes (example) countries in which these systems are currently in operations.

[9] Not only restricted to free-to-air MTV broadcasts, mobile operators offering a single MTV package, activated once, will not necessarily require and automated interface between the mobile and broadcast OSS.

[10] System M (Forward Link Only –FLO) is not included in ITU recommendation ITU-R BT.1833-3 (02/2014) anymore. FLO (also known as MediaFLO) was operated in the USA and as today all services have discontinued.

TABLE 1: SYSTEM CHARACTERISTICS OF MTV SYSTEMS

ITU System reference	System	System characteristics	In (commercial) operations?
System A	T-DMB/AT-DMB	This system, also known as terrestrial digital multimedia broadcasting (T-DMB) system, is an enhancement of T-DAB system to provide multimedia services including video, audio, and interactive data services for handheld receivers in a mobile environment. Multimedia System "A" uses T-DAB networks and is completely backward compatible with T-DAB system for audio services. AT-DMB system is an enhancement of T-DMB system to increase channel capacity of T-DMB and is completely backward compatible with T-DMB system.	**Yes**, T-DMB only. For example in Korea, Ghana, Norway and China
System B	ATSC Mobile DTV/ATSC-M/H	This system, also known as ATSC Mobile DTV, is an enhancement of the ATSC system to provide multimedia services including video, audio, and interactive data service delivery to small (power efficient) receivers, for fixed, handheld and vehicular environments. Multimedia System "B" uses IP-based mechanism with control of time synchronized delivery via buffer modelling for an end-to-end broadcast system including enablement of a return path to facilitate delivery of any type of digital content and service	**No**, tested in the USA and Canada (2013)
System C	ISDB-T OneSeg	The stream signal of this system can be multiplexed with the signal for the fixed reception that coexists within a single stream. And rich content format such as script programme support provides good interactivity on a small device.	**Yes**, for example in Japan, Brazil, Costa Rica and Chile.
System F	ISDB-Tmm	This system is designed for real time and non real-time broadcasting of video, sound, and multimedia content for mobile and handheld receivers based on the common technology of multimedia System C (ISDB-T). High quality video, audio, and multimedia data services can be configured flexibly. In addition, support of a script interpreter for rich content format provides flexibility for the content and service.	**Yes**, in Japan

Also note that the Chinese standards T-MMB and CMMB are not included in this ITU recommendation either. Readily available documents describing the system features and technical characteristics are limited. Both system were implemented in China only. In June 2008 the Standardization Administration China selected T-MMB as the national standard for mobile television services. However China's State Administration of Radio Film and Television favored its own developed CMMB standard. These two standards are in fierce competition with each other. It is unclear what the current implementation situation is.

ITU System reference	System	System characteristics	In (commercial) operations?
System H	DVB-H	An end-to-end broadcast system for delivery of any type of digital content and services using IP-based mechanisms, such as those included in the IP Datacast (IPDC) or OMA BCAST specifications. It is based on DVB-H, which is an enhancement, optimized for handheld terminals, of the DVB-T digital broadcast standard, with which it shares the physical radio environment.	**No**, all DVB-H services were discontinued (mainly in Europe)
System T2	DVB-T2 Lite	An end-to-end broadcast system for delivery of multimedia broadcasting signal to handheld devices based on PLP (physical layer pipes) concept with T2 time slicing technology. This system is designed to optimize and sufficiently improve efficiency of multimedia broadcasting system in trade-off between system parameters such as C/N performance, bit-rate, receiver complexity, etc. enables the simulcasting of two different versions of the same service, with different bit-rates and levels of protection, which would allow better reception in fringe areas	**No**, only tested, for example in the UK and Italy (2012/13)

From Table 1 it can be concluded that from the six systems two systems have been recently tested (ATSC-M/H and DVB-T2 Lite) and three are in operations (T-DMB, ISDB-T OneSeg and ISDB-T_{mm}). One system (DVB-H) is not in operations anymore and the technology is no longer available.

The ISDB-T OneSeg services in operations are all carried as part of a DTTB network (for the delivery of digital terrestrial television services, mainly for fixed/rooftop reception). The transport stream for the OneSeg mobile service shares a portion (one segment) of the total available bandwidth (13 segments). This implies that the deployment of these mobile services is an integrated or part of the network architecture of the ISDB-T "main service" (i.e. the DTTB service)[11]. For the ATSC-M/H standard the same applies. Although not in commercial operations (yet) the ATSC-M/H service shares the same RF channel as a standard ATSC broadcast (the main service). The transport stream (TS) for the M/H service is enabled by using a portion of the total available bandwidth[12].

As Thailand is deploying a DTTB network on the basis of the DVB-T2 standard the ISDB-T OneSeg and ATSC-M/H standards are not an option as these systems are not compatible/cannot be combined with DVB-T2 network architecture.

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[11] See Annex A: ISDB-T for a network architecture overview.

[12] See Annex B: ATSC-M/H for a network architecture overview of the ATSC-M/H services as part of the ATSC main service.

A DVB-T2 Lite service can be transmitted within the same radio frequency channel as the 'normal' DVB-T2 services and hence the DVB-T2 Lite profile is an add-on to the network architecture for the main service, referred to as DVB-T2 Base[13].

Thailand has also adopted the DAB+ system for the deployment of digital terrestrial audio services. Table 1 shows that the (A)T-DMB system can make use of T-DAB networks and is completely backward compatible with a T-DAB system for audio services. This compatibility refers to the network side of the broadcast system whereby (a) an (A)T-DMB service can be injected in the DAB multiplex and carried in the same multiplex[14] (b) a (dedicated) A(T)-DMB multiplex can easily be added into an existing DAB frequency plan (as it has the same bandwidth (1.536 MHz) as the DAB multiplex. However this backward compatibility does not mean that DAB receivers (with a full colour display) can receive (A)T-DMB video services (because DAB receivers don't have an H-264 video decoder)[15].

Hence from a technical point of view only three systems are potential candidates for a transmission standard for MTV services in Thailand:

1. (A)T-DMB;
2. DVB-T2 Lite;
3. ISDB-T_{mm}.

2.1.3 MTV system comparison

The Table 2 provides an overview of the key system characteristics[16]. These system characteristics describe what these system are design for and how they can be configured. All three systems are versatile systems which can be configured in many different ways. However it is important to note that this does not mean that for all system configurations (a) well tested (frequency) planning parameters are available and (b) network/receiver equipment is readily or commercially available[17].

Also the following is important to consider when evaluating the values in Table 2. The values presented in Table 2 assume a dedicated multiplex (and consequently frequencies) for the MTV services. For Thailand, having selected DAB+ and DVB-T2 (for respectively DSB and DTTB), the systems (A)T-DMB and DVB-T2 Lite could also be incorporated into an existing multiplex for DTTB or DSB services (i.e. 'in-band' application)[18]. In such a case the values on the loading of the available

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[13] However a DVB-T2 Lite implementation will need a software update of the network equipment, may need replacement of the modulator and the required number of sites for delivering the mobile services may go up. This may lead to additional frequencies, if these additional sites cannot be incorporated in SFN mode to the existing DVB-T2 Base network.

[14] See Annex C: T-DMB.

[15] However (A)T-DMB receivers can receive DAB+ audio services (as they have an AAC+ decoder).

[16] Values selected for mobile reception conditions from sources; Recommendation ITU-R BT.2016-1 (01/2013) and ITU Guidelines on the migration from analogue to digital broadcasting, January 2014.

[17] For example a receiver will need different filtering for different bandwidths and these different filtering options are not necessarily incorporated in all produced receivers (as a standard).

[18] See for example document EBU Tech 3348 r3 "Frequency & Network Planning Aspects of DVB-T2", Annex 5.

multiplex capacity in Table 2 (respectively item number 6, 7 and 10) do not apply as the MTV service has to share the multiplex capacity with the DTTB and DSB services.

TABLE 2: MAIN CHARACTERISTICS OF THREE MTV SYSTEMS

No	Item	T-DMB/AT-DMB		$ISDB\text{-}T_{mm}$	DVB-T2 Lite
1	Frequency bands	VHF Band III		VHF Band III	VHF Band III, UHF Band IV/V
2	Frequency range	174-240 MHz		174-240 MHz	174-240 MHz, 470-862 MHz
3	Bandwidth/MUX	1.536 MHz		6/7/8 MHz	1.7/5/6/7/8/10 MHz
4	Transmission mode	OFDM		OFDM	OFDM
5	Modulation schemes	DQPSK	B mode (= mobile reception): BPSK over DQPSK	DQSPK / QPSK / 16QAM / 64QAM	QPSK / 16QAM / 64QAM
6	Effective Bit Rate/MUX - @ 6 MHz	0.576 – 1.728 Mbit/s	B mode: 0.864 – 2.304 Mbit/s	8.1 Mbit/s	15-17 Mbit/s Max of 4 Mbit/s per PLP[19]
7	Spectral efficiency (bit/s/Hz)	0.375 – 1.125	0.5625 - 1.875	0.655 – 4.170	0.87 – 4.34
8	Video service encoding / format	Video: MPEG-4 Part 10 AVC (H.264)		Video: MPEG4 Part-10 AVC (H.264)	Video: MPEG-4 Part 10 AVC (H.264), VC-1 (optional)
		Audio: MPEG-4 Part 3 ER-BSAC		Audio: AAC+	Audio: AAC+, AC-3
		Additional data: MPEG-4 BIFS Core2D Profile		Storage type service	Additional data: OMA BCAST
9	Audio service encoding / format	MPEG 1/2 Layer 2 (MUSICAM)[20]		MPEG2 AAC + SBR + PS, Surround MPEG4 ALS/SLS (option)	HE AAC v2 AMR-WB+
		AAC+			
		Visual-Radio : the same as video service format exception the video frame-rate(2-5 frame/sec)			

[19] If all service in the multiplex have the same robustness/protection (i.e. the same PLP) this limitation does not apply.

[20] The audio service is delivered by the DAB system/multiplexer and can either be MUSICAM for DAB and AAC+ for DAB+, see also Figure 55 in Annex C: T-DMB.

No	Item	T-DMB/AT-DMB		ISDB-T_{mm}	DVB-T2 Lite
10	Number of video service (bit-rate: 384 Kbit/s)/MUX[21] - @ 6 MHz	3 services	B mode : 2 – 6 services	21 services	40 – 44 services Max of 11 services per PLP
11	SFN networks possible?	**Yes**		**Yes**	**Yes**
12	System configuration	All services in (DAB) MUX have the same degree of protection / robustness		A number of combinations of video, audio and data services are possible. Different payloads with different degrees of protection can be employed in the same multiplex. Any combination of 1, 3 and 13 segments is possible.	A number of combinations of video, audio and data services are possible. Different payloads with different degrees of protection can be employed in the same multiplex. This is subject to the total available bit rate. Also subject to the maximum bit rate of 4Mbps for each PLP.
13	MTV service can operate 'in-band'? (with systems selected in Thailand)	**Yes**, with DAB(+)[22]		**No**	**Yes**, with DVB-T2[23]

[21] In practice, a variety of bit-rates is applied to video services. For an easy comparison, 384 kbps per video services is applied. As the video encoding is similar the *picture quality* can be assumed to be similar between the systems. If a different bit-rate per service is applied consequently the number of channels will change. It can be argued that for tablets and smartphones with larger screens a higher bit rate will be required (e.g. 640 Kbit/s)

[22] It should be noted that both services (MTV and DSB) will have the same protection/robustness. Typically DAB+ services operate DQPSK, code rate ½ and consequently the MTV service too.

[23] The PLP concept allows for both services (MTV and DSB) to have different levels of protection/robustness.

From Table 2 the following can be concluded in terms of technical system performance:

1. All three MTV systems can operate in VHF Band III and in the 7 MHz ATV raster of Thailand[24];
2. All three MTV systems are based on OFDM transmission technology and are design for mobile reception. They have robust modulation schemes (QSPK) and can operate in SFN mode;
3. Of the three MTV systems T-DMB is less spectrum-efficient and has less effective bitrate capacity per multiplex. The T-DMB system performance has been improved with the development of the AT-DMB standard;
4. Although AT-DMB has improved system performance, its operational costs may be higher as more transmitters per site are needed to carry the same number of services (as compared to DVB-T2 Lite and ISDB-T_{mm})[25];
5. (A)T-DMB and DVB-T2 Lite can operate an MTV services 'in-band' with respectively DAB(+) and DVB-T2 base service transmissions (respectively DTTB and DSB). This may be an interesting option for trial purposes or for limited (in terms of services and coverage) commercial operations. Such an option will require sharing capacity between the base and MTV services[26];
6. DVB-T2 Lite and ISDB-T_{mm} offer the possibility to differentiate the service robustness/protection between services on the same multiplex. This may be an interesting option when services are delivered at different type of receivers, for example tablets, vehicle and hand-set receivers[27].

2.2 LTE system

The Long Term Evolution (LTE) system is an advanced telecommunications platform which has been designed as an all-purpose base platform. This base platform can be further developed for the long term, hence the name. This also implies that network operators cannot upgrade their existing infrastructure (GSM, GPRS and UMTS) to LTE anymore[28]. LTE is considered as the first truly global

---

[24] From a spectrum planning perspective this 7 MHz raster is relevant for when (a) MTV services have to be planned in a situation that ATV is still in operations in the same band (VHF Band III) and (b) for international coordination purposes (i.e. neighbouring country may still operate ATV). After a complete ASO in Band III this raster becomes less relevant (excepting receiver technical considerations).

[25] For example to carry 20 video service (of 384 Kbit/s) AT-DMB in B-mode (for mobile reception) will need 3-4 transmitters per site. For ISDB-T_{mm} and DVB-T2 Lite only one transmitter will be needed.

[26] It could be argued that the MTV services would claim too much capacity from the DSB services so that it would be better to deploy the MTV service on a separated multiplex.

[27] It should be evaluated if this is required as in practice it will mean different coverage areas (with the same number of transmitters) and hence consumer communication that explains the difference.

[28] That is to say the active components cannot be upgraded. However both systems (3G and LTE) can be integrated and traffic can be roamed between them. Passive components like towers and equipment shelters can be re-used.

standard in the telecommunications industry[29]. Hence there are no local or regional versions or alternative systems.

In a further effort to increase the systems efficiency LTE-Advanced (LTE-A) was developed. This platform provided the basis for delivery of mobile video services (as defined in Section 1.4). In order to provide broadcasting functionality the Multimedia Broadcast/Multicast Service (MBMS and the enhanced version -eMBMS) were developed as part of the LTE system's evolution.

Hence this Section is structure as follows:

1. Introduction to LTE;
2. LTE system components;
3. LTE-Advanced;
4. eMBMS.

2.2.1 Introduction to LTE

Mobile telecommunication systems were first introduced in the early 1980s. The first generation (1G) systems used analogue technology for the radio access part. The 2G systems were introduced in the early 1990s. These systems migrated to use digital technology, permitting a more efficient use of the radio spectrum. The 3G technology was then introduced in the 2000's. In the era of 3G, UMTS has the biggest market share as compared to other technology such as CDMA.

The 3GPP (Third Generation Partnership Project) developed the standard of UMTS and evolved this technology over the years to be HSPA, HSDPA, HSUPA. These evolved UMTS systems are also referred to as 3.5G technology. Every step of this UMTS evolution was accompanied with increased data speeds and spectral efficiency improvements.

In 2004, 3GPP began a study into the long term evolution of UMTS (LTE). One of the most prominent design criteria for LTE was to deliver a peak data rate of 100 Mbps in the downlink and 50 Mbps in the uplink. It should be note that this is shared capacity between active users in each cell[30] of the mobile network. Currently LTE-A (LTE Advance) is the next step in further system improvement, promising to deliver a peak data rate of 1000 Mbps in the downlink and 500 Mbps in the uplink.

Table 3 show the history and development of the 3GPP standards and the key features of each release.

Table 3: 3GPP Standards and Releases

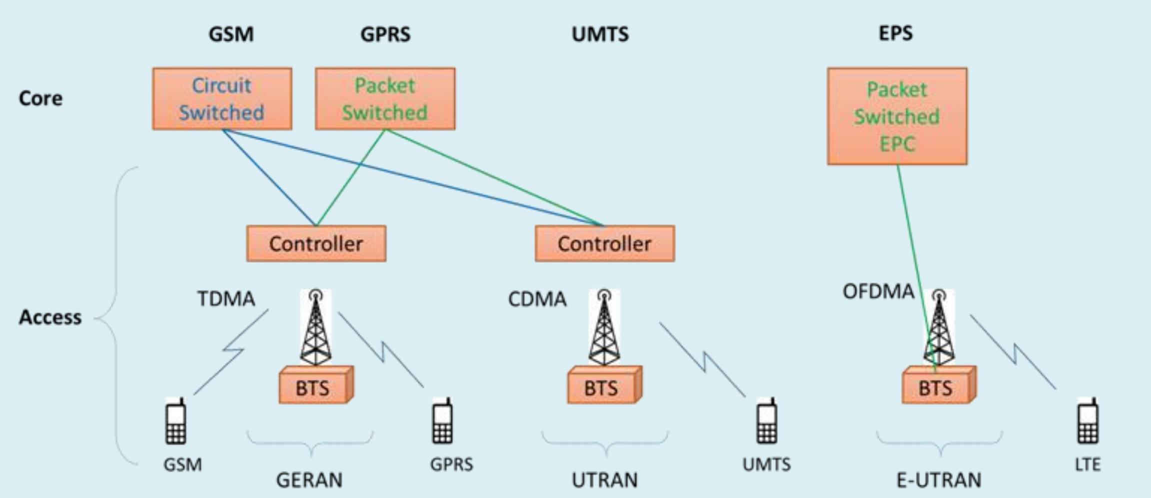
Release no	Release year	Features
R99	2000	UMTS (WCDMA air interface)
R4	2001	TD-SCDMA air interface
R5	2002	HSDPA
R6	2005	HSUPA

[29] The ITU refers to this new family of systems as International Mobile Telecommunications (IMT).

[30] A cell is the service area of a single Base Transceiver Station (BTS).

R7	2007	HSPA enhancement
R8	2008	LTE, SAE
R9	2009	LTE and SAE enhancement
R10	2011	LTE-Advanced
R11	2012	LTE-Advanced enhancement

In summary one can conclude that 2G mobile networks evolved into 3G and 3.5G. Further development of mobile networks was then restarted by establishing a new base: LTE. This development of mobile networks is depicted in Figure 7.



Source: 3GPP

FIGURE 7: EVOLUTION OF MOBILE COMMUNICATIONS NETWORKS

2.2.2 LTE system components

The LTE system architecture is called the Evolved Packet System (EPS), as depicted in Figure 7 on the right hand side. The EPS framework was introduced in 3GPP R8 (see Table 3) to support both real time services and data communications services which are carried and managed by the IP protocol. In the LTE system the IP address is allocated when the mobile is switched-on and released when the user equipment (UE) is switched off. This is different from the GSM and UMTS networks in which a data connection is only setup at the user's request.

LTE provides high spectral efficiency, high peak data rates and short round trip time (RTT)[31]. The EPS framework also includes non-3GPP technologies such as WiMAX, CDMA2000 and WLAN for network

[31] RTT is the response time of the LTE system to a user's data request, comparable to the 'ping' time.

operators having already deployed these non-3GPP systems[32]. These technologies interconnect with the UE and the LTE's core network.

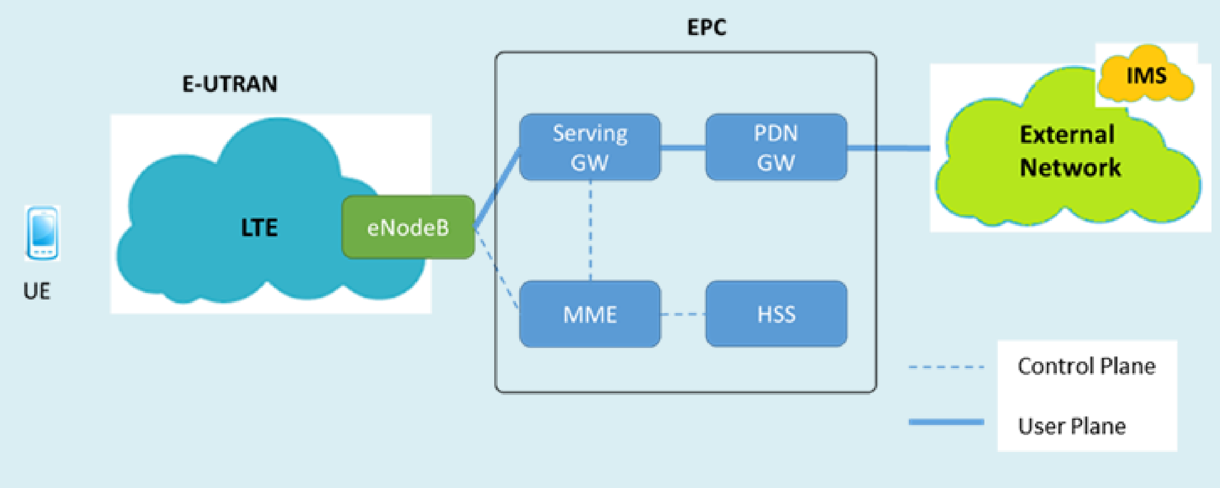
The EPS architecture comprises the following system components:

1. EPC Core Network;
2. Radio Access Network.

EPC Core Network

The EPC (Evolved Packet Core) is the "Core Network" part of the EPS framework. The EPC's function is to route traffic between the Radio Access Network (see next Section) and other (third party) networks, which can include the IP Multimedia Core Network Subsystem (IMS). The EPC introduced in 3GPP R 8 (see Table 3) was designed to support IP protocol both version 4 and 6[33].

Figure 8 shows the EPS architecture when the UE is connected to the EPC over E-UTRAN (LTE radio access network). The Evolved NodeB (eNodeB) is the base transceiver station for LTE's radio access network.



Source: 3GPP

FIGURE 8: EVOLVED PACKET CORE

Figure 8 depicts that the EPC comprises the following components:

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[32] Similar to that LTE and 3G networks can be integrated to roam services, the EPS framework allows for roaming services between these non-3GPP systems and LTE.

[33] IP version 4 is widely used in internet and IP networks. IP version 6 is the upgraded version which provides more features and the most important one is to provide more space for IP addresses. Currently, transition from IPv4 to IPv6 is ongoing around the world.

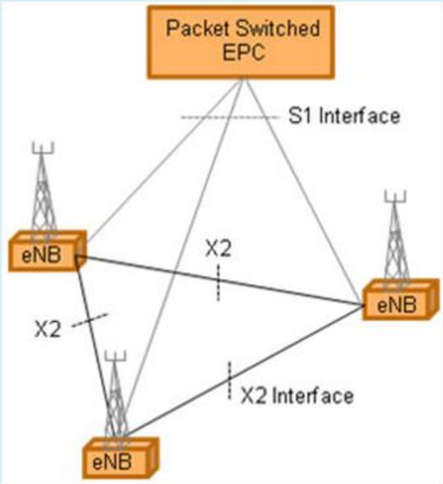
1. Serving Gateway (GW): The gateway transport the IP data traffic between the UE and the external networks. This gateway serves the UE by routing the incoming and outgoing IP packets;
2. Packet Data Network (PDN) GW: is the point of interconnect between the EPC and the external IP networks;
3. Mobility Management Entity (MME): The MME handles the signalling related to mobility and security for E-UTRAN access. The MME takes care of the tracking and paging of the UE when it is idle-mode. The MME is also the termination point of the Non-Access Stratum (NAS). NAS is used to support the mobility of UE and manages IP connectivity between UE and PDN-GW;
4. Home Subscriber Server (HSS): is a database of subscriber-related information. It also provides functions in mobility management such as call and session setup, user authentication and access authorization.

Radio Access Network

LTE use the new access solution based on OFDMA (Orthogonal Frequency Division Multiple Access) technology. In combination with higher order modulation (up to 64QAM), large bandwidths (up to 20 MHz) and spatial multiplexing in the downlink (up to 4x4[34]), the LTE system can achieve the highest theoretical peak data rate on the transport channel of 75 Mbps (uplink). In the downlink, using spatial multiplexing, the rate can be as high as 300 Mbps.

The LTE access network is a collection of networked base transceiver stations (eBN). In this network there is no centralized controller, managing the eBNs. The eNBs communicate with each other via the X2-interface and connect to the core network by the S1-interface as shown in Figure 9. The access network distributes routing intelligence amongst the base transceiver stations as to increase connection set-up time and reduce the time required for a handover between the stations.

[34] 4x4 refers to Multiple Input Multiple Output (MIMO) antenna technology which allows multiple antennas for both transmitter and receiver side. With a 4x4 configuration, it will use 4 separate antennas on transmitter and receiver side. Such configurations can support transmissions of 4 data streams. See also Annex D: LTE-A system improvements.



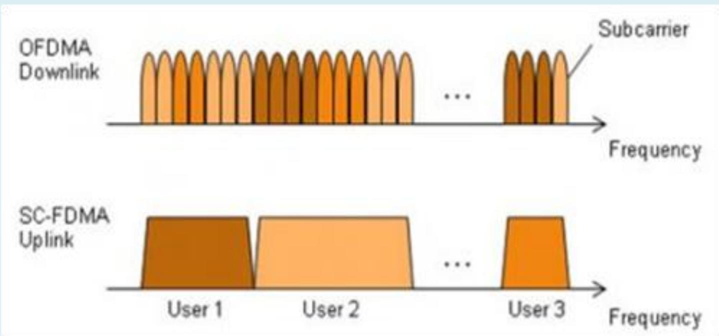
Source: 3GPP

FIGURE 9: LTE RADIO ACCESS NETWORK

In a mobile telecommunications network the radio link between the base transceiver station and UE is two-way interactive; the up (from the EU to BTS) and downlink (from BTS to EU). These links are asymmetrical in the LTE system (and UMTS). The applied technologies are different (and hence the transport capacity):

1. Downlink: Orthogonal Frequency Division Multiple Access (OFDMA);
2. Uplink: Single Carrier - Frequency Division Multiple Access (SC-FDMA).

Figure 10 illustrates the principle of both applied technologies.



Source: 3GPP

FIGURE 10: OFDMA AND SC-FDMA PRINCIPLE

OFDM is a multicarrier technology subdividing the available bandwidth into a multitude of mutual orthogonal narrowband subcarriers. This technology is also commonly applied in the MTV systems (see Table 2 in Section 2.1.3). In the case of mobile telecommunications networks the capacity is shared between multiple users as they access the network for downloading data (hence the Multiple Access in OFDMA). However the OFDMA solution leads to high Peak-to-Average Power Ratio (PAPR) requiring relatively high (and expensive) powers. These high powers are not a problem in the eNB, but would lead in handsets to very expensive handsets. Hence a different solution, SC-FDMA, was selected for the uplink. The SC-FDMA solution generates a signal with a single carrier and consequently with a lower PAPR.

LTE is developed for a number of frequency bands, currently ranging from 700 MHz up to 2.7GHz. Both the network elements as the handsets support this frequency range. LTE is operational in all the included frequency bands across the world.

2.2.3 LTE-Advanced

LTE-Advanced (LTE-A) is a further improvement of LTE's radio access network. The driving force to develop LTE towards LTE-A was to provide higher bitrates in a more cost efficient way, as well as fulfil the requirements set by ITU for IMT Advanced (also referred to as 4G)[35]. Major improvements provided by LTE-A include:

1. Increased peak data rate, downlink 3 Gbps and uplink 1.5 Gbps;
2. Higher spectral efficiency;
3. Increased number of simultaneously active subscribers in each cell;
4. Improved performance at cell edges.

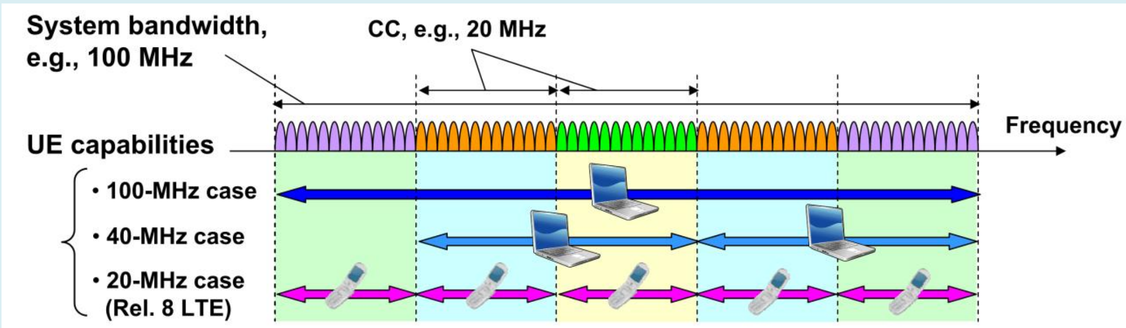
Several advanced technologies were introduced to achieve these system improvements, including:

1. Carrier Aggregation (CA);
2. Multi-Input Multi-output (MIMO) antenna systems;
3. Support Relay Nodes (RN);
4. Coordinated Multi Point operation (CoMP).

Only the first technology will be briefly described below, as this technology is directly relevant for the application of eMBMS (see Section 2.2.4). The other three applied technologies are further addressed in Annex D: LTE-A system improvements.

Carrier Aggregation (CA) is the system's ability to aggregate carriers to form a so called component carrier. The component carrier can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz. In turn, a maximum of five component carriers can be aggregated and consequently the maximum bandwidth is 100 MHz. Figure 11 illustrates the principle of carrier aggregation.

[35] IMT-Advanced systems support low to high mobility applications and a wide range of data rates in accordance with user and service demands in multiple user environments. See document IMT-ADV/1-E released on 7 March 2008. Requirements related to technical performance for IMT-Advanced radio interface(s) refer to document ITU-R M.2134.



Source: 3GPP

FIGURE 11: CARRIER AGGREGATION PRINCIPLE

2.2.4 eMBMS

This Section is split into the following parts:

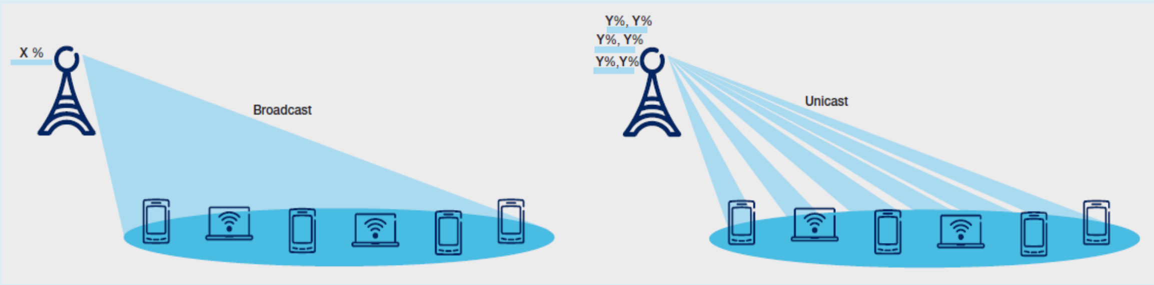
1. eMBMS introduction;
2. eMBMS architecture;
3. eMBMS radio resource management.

eMBMS introduction

Multimedia Broadcast/Multicast Service (MBMS) is a unidirectional transmission from a single source entity to a group of users in a specific area. The MBMS was first introduced in 3GPP R6 (in 2004). MBMS enables the efficient use of UMTS' radio access network and core network resources. MBMS was expected to be implemented by end of 2007. However the MBMS technology has never been deployed by any operator in the world. At that time MTV technologies such as DVB-H, ATSC-MH or ISDB-T technologies were deployed (see Section 2).

The enhanced version of MBMS, eMBMS was standardized in 3GPP R9. The eMBMS system was designed for delivering 20 television services at a data rate of 256 kbps in a 5MHz transmission channel.

In 2014 eMBMS was commercially introduced by Verizon and KT in respectively US and Korea. Like MBMS, eMBMS allows for unidirectional transmission. In an LTE network with eMBMS two types of services can be distinguished; broadcast and unicast. Figure 12 shows the principle of broadcast and unicast.



Source: Ericsson

FIGURE 12: BROADCAST AND UNICAST PRINCIPLE

In the broadcast mode the eMBMS system delivers the same content (or service) to all users and the number of users is unlimited as one transmission channel (or capacity slot) is used for the same content. In the unicast mode (the same) content is delivered to a limited number of users as for each user an individual part of the transmission capacity is allocated (and the transmission capacity is limited). A practical example is the set-up of a phone call or internet session. In unicast mode the number of services can be unlimited as the service or content is routed to each individual user/UE (e.g. a specific video clip). Table 4 shows an overview of both principles.

TABLE 4: BROADCAST VERSUS UNICAST

Broadcast versus Unicast			
Broadcast	One transmission channel per service/content	Limited # of services/content and unlimited # of users	Network resource/capacity allocation independent of # of user
Unicast	One transmission channel per user	Unlimited # of services/content and limited # of users	Resources/capacity allocated when needed/requested by user

Typical use cases for the broadcast mode are:

1. Broadcast: linear television services (see Section 1.2)[36];
2. Traffic off-loading (from the unicast services): broadcasting popular content, daily news clips and software upgrades to the cache/local memory of the UE (e.g. in unicast traffic off-peak hours).

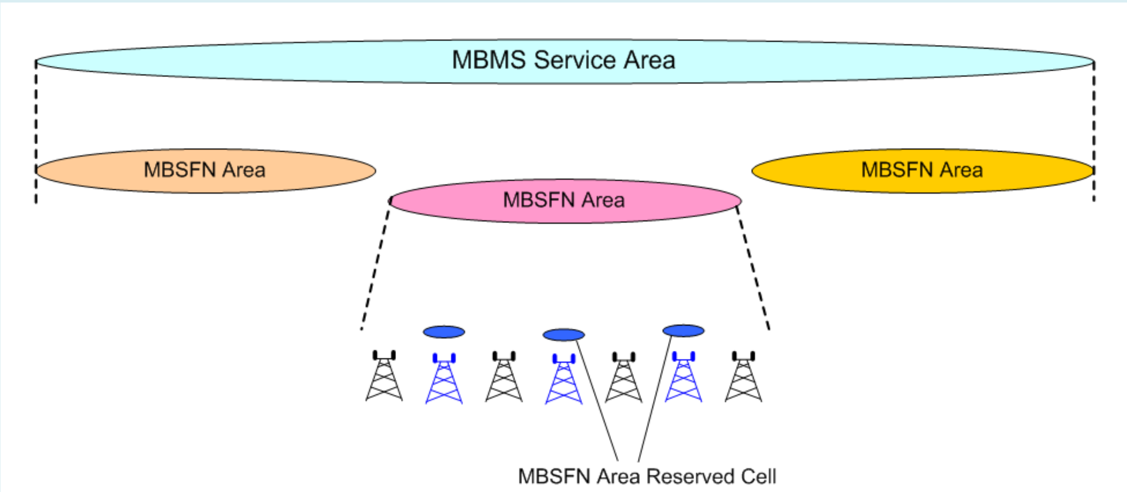
In its purpose and functionality eMBMS traffic off-loading is comparable to filecasting in an MTV system (as indicated in Section 1.4). It should be noted that in combination with a Conditional Access

[36] Linear television services are defined in Section 1.2 as played out on a 24/7 basis. The use cases as illustrated by LTE system vendors do not include broadcasts on the basis of 24/7. They mention local/regional and venue broadcast whereby network resources are temporarily allocated.

System (CAS) system individual users can be addressed in a MTV system, like in a mobile/LTE network[37].

eMBMS architecture

The eMBMS system when in broadcasting or unicasting mode can utilize the Single Frequency Network (SFN) technology (like with the MTV systems). The application of SFN technology is indicated with MBSFN in the LTE system. Figure 13 illustrates the MBSFN principle in a LTE network.



Source: 3GPP

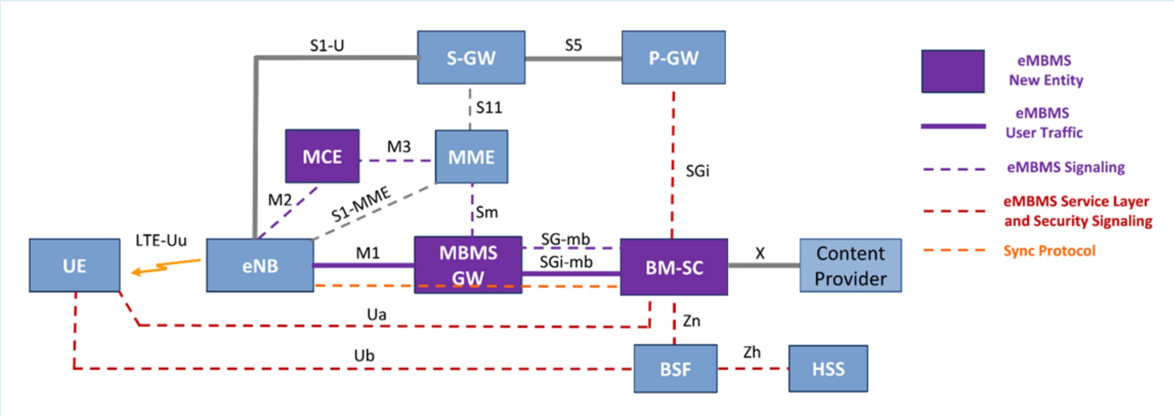
FIGURE 13: MBSFN PRINCIPLE

In contrast with MTV systems, the MBSFN technology allows the network operator to dynamically include or exclude individual base transceiver stations in a SFN (see blue stations in Figure 13). In this way the operator can form SFNs at a temporary basis and in selected areas of the LTE's total network coverage area.

The eMBMS system leverages the investments in a LTE's radio access network[38]. It sits on top of LTE's radio access network and can be considered as an extension of LTE's core network (see Section 2.2.2). Figure 14 shows in some detail how the eMBMS system components can be integrated in an existing LTE ecosystem.

[37] It should be noted that with hybrid mobile network (as explained in Section 2.1), the service provider/network operator has also the option to select the Digital Rights Management (DRM) system of the mobile network. The selection of this system addresses the strategic issue of customer ownership.

[38] LTE's radio access network should be LTE-A (see Section 2.2.3) for delivering a significant number of television services (and not allocating too much network capacity to these services) as carrier aggregation (i.e. pulling capacity together) is needed (and carrier aggregation is part of LTE-A).



Source: Qualcomm

FIGURE 14: INTEGRATION OF EMBMS SYSTEM COMPONENTS

The functionality of each of the eMBMS system components (in Figure 14) can be briefly listed as follows:

1. MCE (Multi-call/multicast Coordination Entity): This is a logical entity – this does not preclude the possibility that it may be part of another network element. It includes the following functionality:
    a. Admission control and allocation of the radio resources for all eNBs in the MBSFN area for multi-cell MBMS transmissions;
    b. Controlling suspension/resumption of MBMS session within MBSFN area;
2. MBMS GW (MBMS Gateway): This is also a logical entity and has the following functionality:
    a. Sending/broadcasting of MBMS packets to each eNB transmitting the service;
    b. Uses IP multicast as the means of forwarding MBMS user data to the eNB;
    c. Performs MBMS Session Control Signalling (session start/update/stop) towards the E-UTRAN via MME;
3. BM-SC (Broadcast/Multicast Service Centre): This centre has the following main functions:
    a. Authentication, authorization content provider;
    b. Charging and the overall configuration of the data flow through the core network.

For the above listed functionality it can be concluded that BM-SC provides functionality that is normally found in the CAS and Subscriber Management System (SMS) of pay-tv operator/broadcaster.

It should be noted that in case of broadcasting television services free-to-air (FTA) over an eMBMS system and having a regulatory requirement that viewers/users can watch these services without a

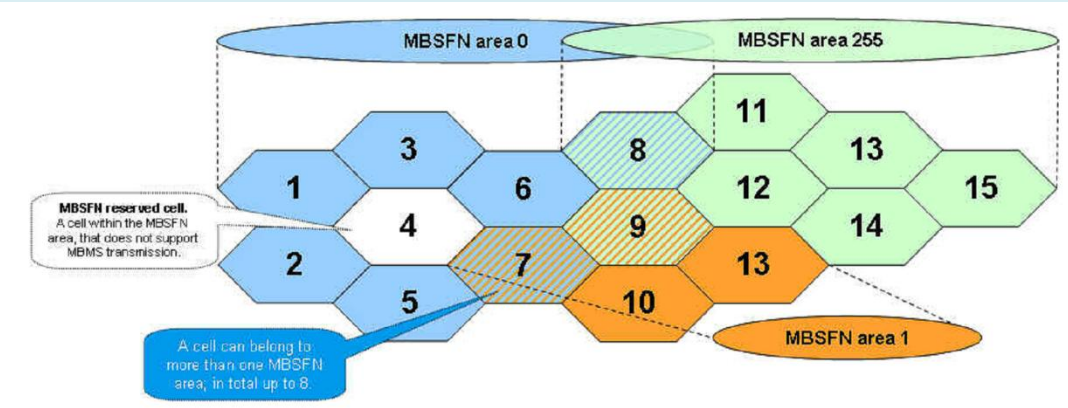
SIM-card, will require that some typical television functionality is implemented according to an additional 3GPP standard, defined in TS 26.346[39].

eMBMS radio resource management

As indicated before the eMBMS system enables flexible SFN broadcasts. In the LTE framework SFN broadcasting is phrased as follows. The MBSFN area is an area whereby of a group of base transceiver stations or cells are synchronized to transmit content at the same time. Like in a broadcast SFN the content carried in the same transmission channel (i.e. multiplex) has to be the same (otherwise the sites in the SFN will interfere with each other and not contribute to the SFN gain).

The eMBMS system can exclude cells that cannot or should not operate in SFN mode (the so-called MBSFN Area Reserved Cells). All synchronized cells within an MBSFN Area contribute to the MBSFN transmission and advertise their availability. The UE may only consider a subset of the MBSFNs that are configured in the LTE network. This functionality is for example of interest when the subscriber or user is only interested in receiving services from selected MBSFNs (e.g. when the eMBMS system is used for broadcasts in different sports venues).

Figure 15 shows a simplified example of three different MBSFN areas, area 0, area 1 and area 255[40]. Radio cells 7, 8 and 9 belong to more than one MBSFN area[41]. Cell 4 has the status of a “reserved cell” which means in this radio cell no MBMS transmission will be supported.



Source: Rohde-Schwarz

FIGURE 15: MULTIPLE MBSFNS IN LTE NETWORK

[39] See EBU report TR027, “Delivery of Broadcast Content over LTE Networks” on the topic of User Service Discovery (USD). See also Chapter 7 in this report.

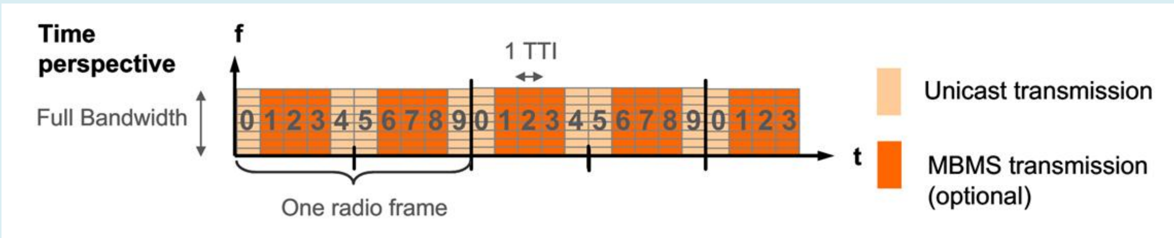
[40] 3GPP allows a maximum of 65,536 service areas in a network.

[41] 3GPP allows one cell belonging to up to 8 MBSFN areas and it can serve multiple Service Areas.

Cells 7, 8 and 9 can operate in different MBSFNs as the UE can communicate with the network and SFNs can be dynamically formed. Hence cells 7, 8 and 9 can switch their SFN operations between the different SFNs they are assigned to.

Release R9 (see Table 3) defined the System Information Block Type2 (SIBType2). It defines which radio frames in the transmission channel can be allocated to broadcast (MBMS) or unicast services. It is important to note that this allocation is dynamic. The network operator can change the allocation of its radio resources/sub frames over time. In other words the operator can switch the broadcast (or unicast mode) on and off.

The eMBMS system uses so-called MBSFN subframes to carry the broadcast services. A single radio frame comprises 10 subframes and up to six subframes can be allocated to the broadcast services. The MBSFN subframes can be used by all MBSFN enabled cells in the LTE network (see Figure 15). Figure 16 shows this principle of allocating MBSFN subframes.



Source: EBU

FIGURE 16: MBSFN SUBFRAMES PRINCIPLE

Figure 16 shows that a maximum of 60% of the available radio capacity can be allocated to broadcasting services. With LTE-A functionality the total radio capacity can be increased (> 40 MHz) by aggregating carriers (see Section 2.2.3).

The practical capacity available for broadcast services on an eMBMS system was simulated[42]. Under a number of practical assumptions (including applied inter-site-distance, modulation and coding scheme) were made for this simulation. The results showed that with the allocation of one subframe to the broadcast services and having 20 MHz bandwidth available, the eMBMS can make in the range of 5 Mbps available for broadcasting. Depending on the required picture quality a number of television services can be carried. For example when allocating 384 Kbps per services the eMBMS can carry approximately 12 -13 services (when the broadcast mode is switched on). Allocating 256 Kbps would result in approximately 19-20 services[43].

[42] See Ericsson Technical Journal, Delivering content with LTE Broadcast, February 11, 2013.

[43] For more issues on (MTV and eMBMS) system implementation considerations please refer to Chapter 3.

3. MTV and LTE implementation aspects

This Chapter will cover key implementation aspects for both MTV and LTE systems. It will cover network implementation, receiver availability and business developments.

Consequently this Chapter is structured as follows:

1. (A)T-DMB;
2. ISDB-Tmm;
3. DVB-T2 Lite;
4. LTE.

3.1 (A)T-DMB

As can be observed from Table 1 in Section 2.1.2, only T-DMB systems are in operations. The AT-DMB systems has been defined and standardised but not taken into operations. In Korea, the leading T-DMB country, there are also no plans to take AT-DMB system into operations. The latest developed is that in January 2013, KBS (the Public Service Broadcaster) launched Smart DMB which combines 3G/4G and T-DMB networks for delivering hybrid MTV services. This new service does not include the AT-DMB standard.

Although AT-DMB has been standardised no receivers or network equipment is/will be commercially/readily available[44]. Also experience with in-field/commercial system performance is very limited to none. Neither frequency planning parameters are defined and tested. In other words, if Thailand would opt for AT-DMB it will embark on an extensive journey of testing and developing the practical implementation of this system. As Korean parties have no plans to launch AT-DMB getting Korean support in this matter will be difficult. Without the support of Korean expertise (e.g. KBS and ETRI) selecting the AT-DMB system seems to be a risky option for Thailand.

Hence in this Section only the T-DMB system is evaluated in terms of:

1. Network implementation aspects;
2. Receiver availability & pricing;
3. Business model and technology developments.

3.1.1 Network implementation aspects;

If T-DMB would be considered for Thailand, launching a MTV service on the T-DMB standard will have some technical implementation issues and options to be carefully evaluated, including:

1. T-DMB receivers in Korea operate in a 6 MHz raster, it should be verified if the T-DMB system would be implemented in Thailand (with a 7 MHz raster) whether receivers produced for the Korean market can operate without modifications in a 7 MHz raster;

[44] A limited number of prototype network equipment is available, for example Rode & Schwartz AT-DMB Exciter Prototype (Sx801).

2. T-DMB receiver/equipment roadmaps of various manufacturers (including chipset manufacturers) should be carefully evaluated as to assess the long term availability of such chipsets, receivers and network equipment;
3. If T-DMB would be implemented as in 'in-band' service with DAB+ (see Figure 55 in Annex C: T-DMB), it should be verified in practice that[45]:
    a. Network equipment is readily available for injecting a T-DMB stream into a DAB+ multiplex system;
    b. DAB+ receivers will ignore the T-DMB services;
    c. MTV services can run on relative low bit rate (depends on receiver type/screen) and are not consuming too much capacity for the DSB services.

If a DMB implementation would be considered, such an implementation could rely on the experience of an Emergency Warning System (EWS) as implemented in Korea. In 2007 Korea implemented a EWS on the basis of the DMB system. The EWS system uses the Fast Information Data Channel (FIDC) in the DMB stream. This system and its messages have been standardized[46].

3.1.2 Receiver availability & pricing

As no AT-DMB receivers have been commercially produced, this Section only considers T-DMB receivers. Since 2005 more than 62 million T-DMB receivers have been sold in Korea. In China, Norway, France and Ghana T-DMB services are reported to be commercially available but no receiver sales data is publically available[47].

Receiver availability

Figure 17 provides an overview of the type of receivers which have been sold, mainly in Korea[48].

[45] To date no implementation are known whereby T-DMB streams are injected in a DAB+ multiplex.

[46] For more information on EWS see http://worlddabeureka.org/2012/10/25/emergency-warning-systems-in-dab/.

[47] See www.worldab.org and ETRI presentation "Evolution of T-DMB", dated 6 February 2014.

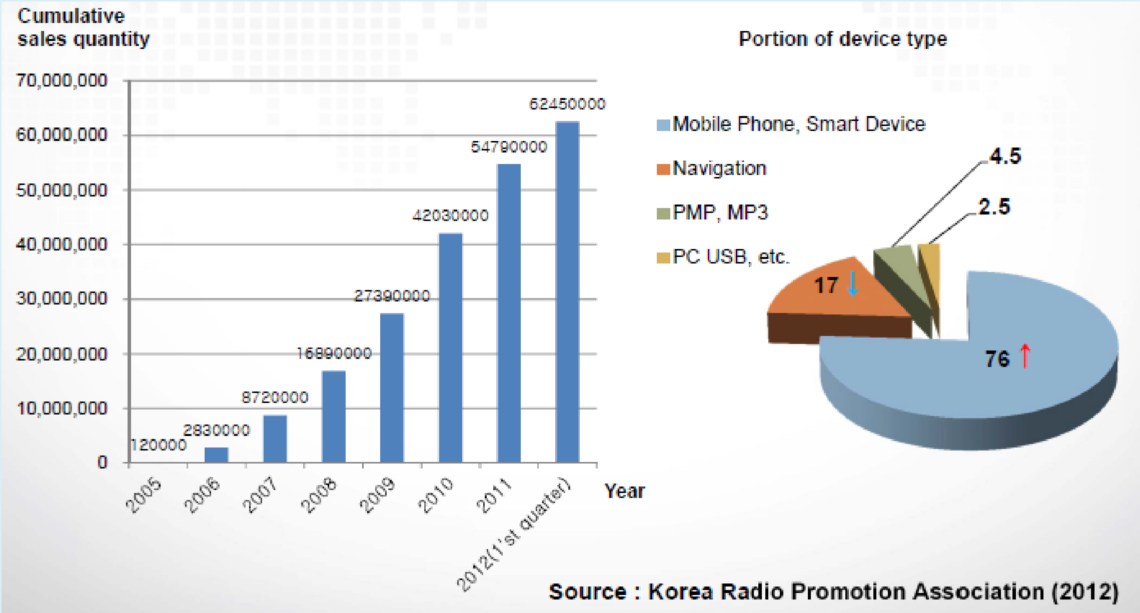
[48] From ETRI presentation "Evolution of T-DMB", dated 6 February 2014.

Source: ETRI

FIGURE 17: AVAILABLE T-DMB RECEIVER TYPES

The majority of T-DMB enabled receivers are produced by Korean manufacturers (like Samsung and LG). The number of available T-DMB equipped handsets/smartphones has gone down over the years. The current available T-DMB enabled smartphones seem to be limited to a few high-end models of Samsung and LG. A number of other (Korean produced) receivers, like tablets, have T-DMB build-in. Figure 18 shows the cumulative sales of T-DMB enabled receivers. The figure shows the latest published figures and they run till 2012[49].

[49] See footnote 48.



Source: ETRI, Korean Radio Promotion Association

FIGURE 18: CUMULATIVE SALES OF T-DMB ENABLED RECEIVERS

The latest sales figures on T-DMB enabled handsets have not been published recently. This should be interpreted with caution.

Receiver pricing

The additional costs for integrating a T-DMB receiver in a smartphone or tablet are small (USD 2.50). As described above the T-DMB enabled smartphones are the top-models and their price range from USD 650 as much as USD 1,000. In such devices the additional costs of integrating a T-DMB receivers is relatively low.

3.1.3 Business model and technology developments

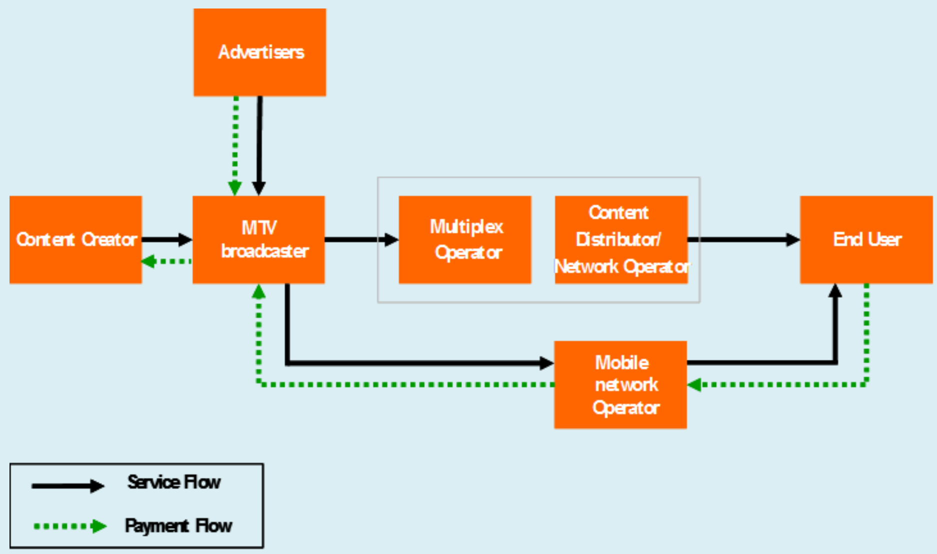
The following developments around the T-DMB technology and service include:

1. Business model;
2. Smart DMB;
3. Smart DMB service extensions;
4. Euro-chip set.

Business model

As the T-DMB services are operated on a commercial basis it is important to consider its business model. The T-DMB business model is based on providing FTA services. With reference to the ITU Guidelines[50], the corresponding business model is depicted in Figure 19.

[50] See ITU Guidelines on the Transition from Analogue to Digital Broadcasting, 2014 edition, see section 3.4.2.



Source: ITU

FIGURE 19: BUSINESS MODEL FOR MTV IN SOUTH KOREA

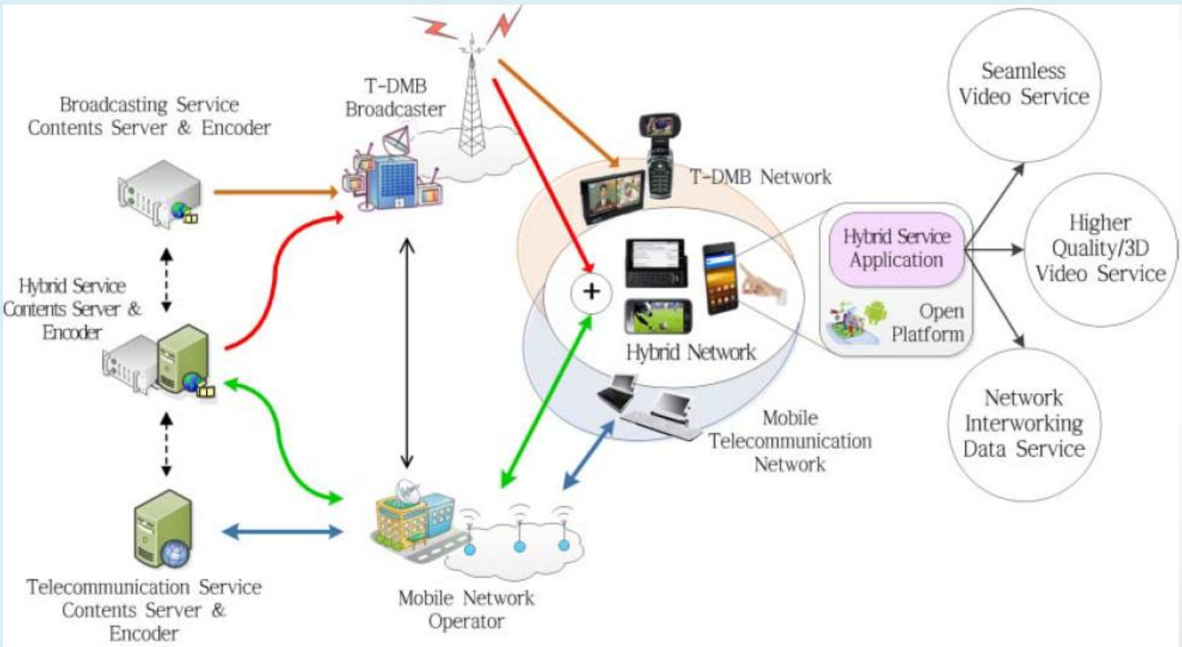
In South Korea (and Japan for the OneSeg service), a FTA business model for MTV services is applied as depicted in Figure 19. Basically this model is not different from the FTA models as applied for DTTB services. In the MTV market of T-DMB in South Korea, the MTV services are offered for free to the end-users. The MTV broadcasters own the (MTV) content and also directly operate their own shared MTV network. They directly distribute audio, video, and data (TPEG, EPG, News, Weather, etc.) to the MTV viewers through their shared MTV network.

The MTV broadcasters are existing broadcasters that re-transmit their content in prime time over their shared MTV network. Also some newly produced MTV programs (news, weather, traffic information, etc.) are broadcast too.

As observed during the country visit, in this FTA model advertising income is the main source of income. Fees for interactive/data services were marginal. Although no hard evidence could be collected on the profitability of the MTV services, it is generally argued that the model is loss making as no new advertising revenues can be found. However as the additional costs to the broadcasters are minimal, the service is continued.

Smart DMB

As indicated in the introduction of this Section the AT-DMB system will not be further developed nor introduced. The latest developed around the T-DMB system is the introduction of Smart DBM. This service was launched in 2013 and the system integrates the T-DMB broadcast network with a 3/4G mobile or Wifi network. This hybrid system delivers next to MTV services interactive services such Video on Demand (VOD), enhanced service information and social networking (e.g. capturing a video scene and include the clip in a chat session). The Smart DMB system architecture and functionality is similar to ISDB-T_{mm}. (see Section 3.2). The network architecture of Smart DMB is illustrated in Figure 20.



Source: ETRI

FIGURE 20: SMART DMB NETWORK ARCHITECTURE

From Figure 20 the following can be observed:

1. Hybrid services are only available in areas where both networks (T-DMB and 3/4G) provide coverage (the white coverage area). For example retrieving enhance service information (delivered by the IP network) about the program being watched (on the T-DMB platform) is only possible where both networks are available. The coverage and capacity of the Thai mobile networks (3G/4G) should be considered, as well as the intended coverage and available capacity of the DAB+ network (in case of an 'in-band' service launch) or the network coverage of T-DMB network (if launched as an independent network from DAB+). Obviously the telecommunications and broadcast network should match as much as possible;
2. The 3/4G network(s) can be used to enhance the picture quality of the T-DMB service. By combining the T-DMB video stream (SVC base layer) and an additional stream (SVC enhancement layer) from an IP streaming server (3/4G network or WiFi) the picture quality is enhanced. Also this functionality will require both networks to be available in the same area. This is an interesting option in the light of the perceived lower picture quality of T-DMB video services (due to the limited capacity and the larger screens of contemporary smartphones and tablets)[51];
3. By handing over the video services from the T-DMB network to the 3/4G/WiFi network (or the other way around) the coverage area can be extended. This handover is seamless.

[51] Especially in Korea with a nationwide 4G network and a penetration of 50%, Korean smartphone users are used to having video delivered at high bitrates (although mainly short and long form video, not necessarily linear television).

However the picture quality may change if the available transport capacity on the IP networks (3/4G/WiFi) is (temporarily) different than in the hybrid or T-DMB coverage area. Also here available capacity of the 3/4G networks should be carefully considered and agreed with the mobile network operator;

4. Although the Smart DMB services utilize both networks, the operational and business processes (for delivering and billing the interactive services) are not integrated. All content servers and encoders for the (interactive) services are all managed by the broadcast network operator. Basically the broadcaster network operator manages a synchronised (with the broadcast) web server which delivers the interactive content to a Content Deliver Network (CDN)[52] provider. It should be noted that this is different from the model adopted in Japan by NOTTV (see Section 3.2).
5. Although Figure 20 shows one T-DMB network, the actual situation is that six network operators manage six independent networks in Seoul metropolitan area. These network operators are integrated companies as they are also the MTV service provider (i.e. broadcaster). Three of the six are incumbent broadcasters and three are newly established DMB broadcasters[53]. Apart from these 6 metropolitan broadcasters there are 13 regional broadcasters. Hence 19 different networks are deployed. These broadcasters/network operators do share sites, but active network components are not shared.

With Smart-DMB the handset requirements are no different from the previous T-DMB handsets. As long as the handset has a T-DMB receiver and is IP connected, the Smart-DMB software (i.e. an app) can be downloaded and installed. With a Smart DMB enabled handset the end-user can opt for switching on or off the enhancement of the T-DMB delivered video content. Switching on this enhancement will result in an IP stream of up to 300 Kbps. Consequently this will consume MBs from the end-user's data package. However having the same television service (with the same picture quality) delivered over a 3G/4G network only, will consume three times more data capacity, let alone network congestion (when many users in the same cell stream the service).

The current business model (including Smart DMB) is advertising and license fee based. The following revenue streams can be listed:

1. Zapping advertisement. When the receiver switches between television services, the user is presented an advertisement;
2. Banner advertisement. In the display an overlay over the television service is created, containing an advertisement (i.e. banner);

[52] A CDN providers is a provider specialized in delivering IP video content over the Internet, by means of having a distributed database with servers sitting as close as possible to the end-user.

[53] KBS, MBC and SBS are the incumbent broadcasters. YTNDMB, KoreaDMB and U1 Media are three newly established broadcasters.

3. In-channel advertisement. The 'normal' broadcast schedule includes advertising slots. The DMB platform can deliver the advertisement in these slots to people on the move (which could entail more 'eye-balls'[54]);
4. Traffic information (on the basis of TPEG). For each receiver build into a car, the car manufacturer pays a one-off license fee;

Of the four above listed revenue streams the largest stream is the license fees for the traffic information. For collecting and sharing these revenues between broadcasters/network operators a alliance was formed. This revenue sharing mechanism does not apply for the in-channel advertising.

With Smart DMB it is possible to collect end-user information such as which television services they watch or what kind of interactive service they use. This is possible because the end-user selects a DMB service by sending a request over the IP network. This may be obvious for the interactive services, but this IP based service selection also applies when the user is changing television services. Selecting a television service can also be done on the handset by instructing the DMB receiver but the service selection data will not be collected (if not polled from the receiver).

Smart DMB service extensions

In a further effort to improve services and the business case the following service extensions are planned for:

1. Improve picture quality. Although Smart DMB enhances the picture quality, it is felt that it cannot match the picture quality of LTE delivered video. The head-ends of the DMB services will be upgraded to include the latest encoding technology: HVEC (i.e. H.265). New video encoders are needed for this. However modern smartphones (equipped with the Qualcomm snapdragon 800 chipset or higher) already include the H.265 decoder and can process the video stream[55]. With H.265 DMB variant the screen resolution will be increased from the current 480p (640x480) to 720p (1280x540);
2. Low power DMB. This service is meant for event broadcasting in a small area around the location where the event is organised (for example in and around a football stadium). It is for temporary broadcasts with low powers so that it fits in the so-called 'white spaces' in the DMB allocated spectrum. A motorised vehicle is equipped with a DMB head-end (i.e. encoders and multiplexer) and transmitter. This mobile DMB vehicle is directly fed from the mobile studio/OB vehicle, also present at the event location.

Euro-chip set

The Euro-chip set is an initiative from the European Broadcasting Union (EBU) to promote the availability of integrated chip sets combining DAB/DAB+/DMB and FM functionality onto a single

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[54] In a situation where the MTV services are the same as the DTTB services, distribution of these televisions services over a mobile platform (i.e. MTV) would not necessarily lead to more (different) 'eye-balls'. This is especially the case when the DTTB services have a high penetration rate.

[55] For example the following Samsung models; Galaxy Note 3 use snapdragon 800 and Galaxy Note 4 use snapdragon 805. Please note that the Galaxy Note 3 is equipped with Samsung's Exynos chipset in Thailand. This chipset does not support LTE.

cheap chip-set. These combined chip sets are already available in the market. It is basically a marketing campaign from the EBU to invite chipset and receiver manufacturers to produce these sets as well as broadcasters to develop hybrid services. Mobile handsets and tablets equipped with this digital functionality can provide a technical platform for broadcasters to develop interactive/hybrid services (like illustrated with Smart DMB).

However this market campaign is focussing on the development of the hybrid radio services and not on developing hybrid MTV services. Therefore this development is only of interest for T-DMB based MTV services for bringing down receivers costs[56].

3.2 ISDB-T_{mm}

As discussed in the introduction, ISDB-T OneSeg services in operations today are part of a DTTB multiplex. Thailand operates DTTB multiplexes on the basis of DVB-T2. Consequently ISDB-T_{mm} is the only option if a standard from the ISDB family would be adopted[57]. Also the ISDB-T_{mm} will operate as a standalone platform.

In this Section the ISDB-T_{mm} is evaluated in terms of:

1. Network implementation aspects;
2. Receiver availability and pricing;
3. Business model and technology developments.

3.2.1 Network implementation aspects

ISDB-T_{mm} is deployed in Japan. ISDB-T_{mm} is design to operate as a hybrid system whereby the functionality of a broadcasting network is integrated with that of a telecommunications network (i.e. an IP based, switched network). The system architecture of ISDB-T_{mm} is similar to Smart DMB (at top level). As implemented in Japan, ISDB-T_{mm} will require close collaboration between the broadcast and telecommunications/mobile network operator.

In Japan, the ISDB-T_{mm} service is delivered under the brand name NOTTV. Figure 21 shows how NOTTV' service delivery is integrated across the telecommunications networks (LTE/3G) and the ISDB-T_{mm} network.

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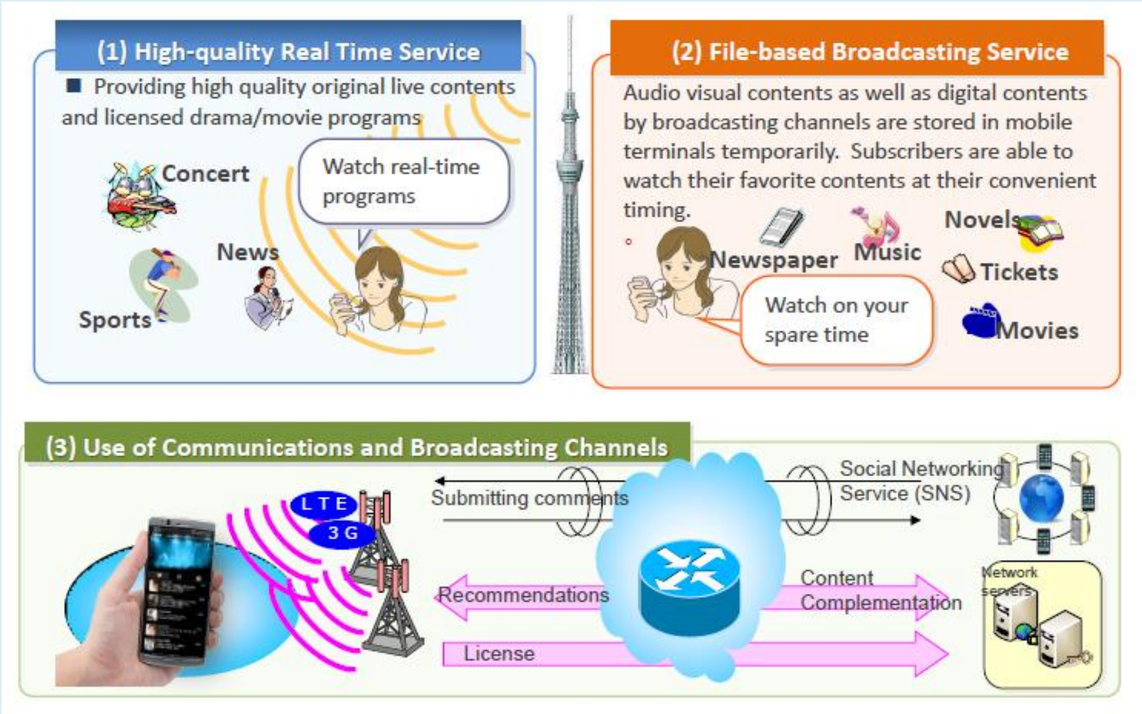
[56] In this context it should also be noted that RadioDNS a proposed set of common specification is for hybrid radio services (e.g. for interactive/targeted advertising and shopping).

[57] Please note that ISDB-T_{sb} is the other terrestrial standard but this one is design for DSB.



Source: NOTTV

FIGURE 21: NOTTV SERVICE CONCEPT

The close relationship between the telecommunications and broadcasting industries is reflected in MMBI's ownership structure. MMBI is a company which is held for 61% by NTT DoCoMo[58]. The Japan MobileCasting company, a 100% subsidiary of MMBI, owns and manages the ISDB-T_{mm} network.

If ISDB-T_{mm} would be considered for Thailand, launching a MTV service on the ISDB-T_{mm} standard will have some technical implementation issues and options to be carefully evaluated, including:

1. As Thailand has opted for DAB+ and DVB-T2, ISDB-Tmm cannot be deployed as 'in-band' service. As indicated in Section 2.1.3, an in-band service deployment would provide the possibility to launch MTV services with relative low additional network investments. An introduction of ISDB-Tmm would imply a deployment of an independent network. The deployed ISDB-Tmm system would also require additional skill sets and training for the broadcast network operator;
2. In Japan, ISDB-T_{mm} is implemented in a 6 MHz channel raster in a VHF band ranging from 108 to 222 MHz (called V-High). If Thailand would opt for ISDB-T_{mm}, it would operate in the broadcast allocated VHF Band III, ranging from 174 MHz to 240 MHz. As with T-DMB (see Section 3.1.1), it should be verified whether ISDB-T_{mm} receivers produced for the Japanese market can used without modifications in the Thai 6 MHz raster;

[58]MMBI's other shareholders are content and equipment providers, including companies like Fuji Media Holdings, Nippon Television Network Corporation, Tokyo Broadcasting System Holdings, Fujitsu Limited, NEC Corporation, Panasonic Mobile Communications Co., Sharp Corporation and Toshiba Corporation.

3. Hybrid services are only available in areas where both networks (ISDB-T_{mm} and 3/4G) provide coverage. For example retrieving enhance service information (delivered by the IP network) about the program being watched (on the ISDB-T_{mm} platform) is only possible where both networks are available. The coverage and capacity of the Thai mobile networks (3G/4G) should be considered, as well as the intended coverage of the ISDB-T_{mm} network;
4. By handing over the video services from the ISDB-T_{mm} network to the 3/4G/WiFi network (or the other way around) the coverage area can be extended. This handover is seamless when the same service is carried and subscribed to in both networks. However the picture quality may change if the available transport capacity on the IP networks (3/4G/WiFi) is (temporarily) different than in the hybrid or ISDB-T_{mm} coverage area. Also here available capacity of the 3/4G networks should be carefully considered and agreed with the mobile network operator;
5. As implemented in Japan, the ISDB-T_{mm} services requires the broadcast and mobile network operator to agree on business model, operations (including customer ownership, servicing, traffic balancing and service prioritization) and technical deployment of the service. Especially negotiations on business model and operations can be very time consuming and complex. Such closely related business operations will have impact on the regulator too, including:
    a. Licensing (ownership structures, content and spectrum rights);
    b. Licensing fees (what are the scope of revenues and who generates the revenues);
    c. Regulatory monitoring (what are the QoS levels and who is responsible, including deployment obligations).

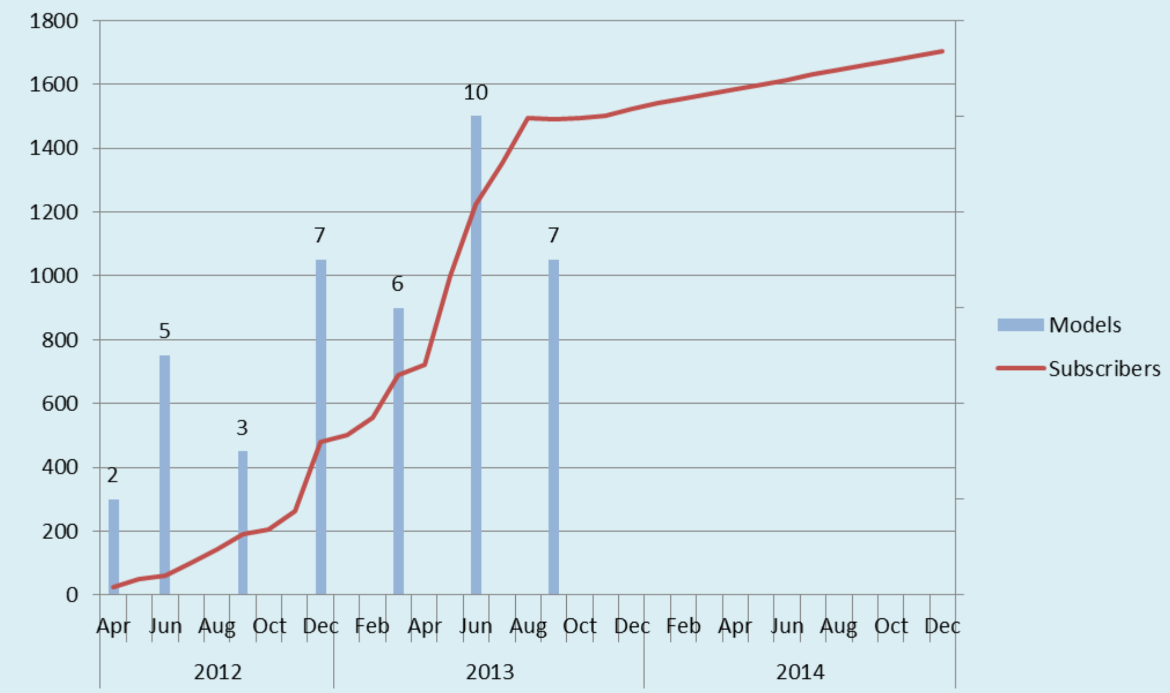
If an ISDB-T_{mm} system implementation would be considered, such an implementation could rely on the experience of an Emergency Warning System (EWS) as implemented in Japan. Japan's Meteorological Agency feeds its emergency information directly into NOTTV's head-end and emergency message (including earthquake, tsunami and weather alerts) are directly superimpose over the regular video service. These EWS messages are also broadcasted on the ISDB-T platform for DTTB services.

3.2.2 Receiver availability and pricing

Smartphones and tablets equipped with an ISDB-T_{mm} receiver are commercially available in Japan. Japan is the only market that has ISDB-T_{mm} services commercially in operations. Hence the market for ISDB-T_{mm} receivers is led by developments in Japan. After television ASO in Japan, the whole V-High band became available for MTV services.

Receiver availability

Since NOTTV' service launch in April 2012, over 1.7m people subscribed to the service. The latest subscriber data available is of December 2014. As a minimum one can assume that this number of 1.7m is equal to the cumulative sales of ISDB-T_{mm} receivers. Figure 22 shows and overview of the subscriber uptake and the number of ISDB-T_{mm} enabled receivers introduced in the market.



Source: NOTTV, adapted

FIGURE 22: NOTTV SUBSCRIBERS (X 1000) AND HANDSET MODELS

Some handset models of NOTTV are displayed in Figure 23. It should be realised that these ISDB-T_{mm} enabled models come together with subscribing to the service[59]. This is different from the T-DMB market in Korea where the MTV services are all free (i.e. FTA). In other words, in Japan the ISDB-T_{mm} receiver market is vertically integrated with the service provider[60]. In Korea the MTV receiver market is a horizontal market. That is to say, MTV receiver buyers and users don't have a direct customer relationship with the service provider (for example a billing relationship).

[59] Without a subscription ISDB-T_{mm} enabled sets are also purchased in the DoCoMo webshop.

[60] That is to say DoCoMo. In addition it should be noted that ISDB-T OneSeg services are also broadcasted (as part of DTTB service bouquet) in Japan. These services are FTA and ISDB-T receivers are distributed in a horizontal market, like in Korea.

Source: NOTTV

FIGURE 23: 2013-14 NOTTV MTV HANDSET MODELS

NOTTV keeps launching new models every quarter. In total over 50 ISDB-Tmm enabled models are available on the website of NOTTV. Most of them are also LTE enabled.

With an ISDB-T_{mm} network, or any other MTV network, also fixed or indoor coverage is provided. Hence NOTTV is also offering a STB for at home watching, called TV Box[61]. Similarly, they also offer a stand for docking a NOTTV smartphone or tablet. With these devices a cable and separate indoor antenna is provided as an extra. Clearly with TV Box NOTTV is also competing on the DTTB market[62].

Receiver pricing

As stated before ISDB-T_{mm} enabled models come together with subscribing to the NOTTV service and/or any other subscription plan from DoCoMo. Under various subscription plans NOTTV enabled handsets can be acquired against large discounts (up to 100%). However ISDB-T_{mm} enabled sets can also be purchase without subscribing to the NOTTV services. NOTTV also offers FTA services and buying an ISDB-T_{mm} enabled set will suffice for receiving these services. All NOTTV enabled sets are purchased in the webshop of DoCoMo. NOTTV handset (all smartphones or tablets) prices without a subscription plan range from USD 850 (for a Samsung Galaxy S5) to USD 180.

[61] An IDTV can be connected to the NOTTV TV Box with an HDMI cable or the NOTTV services can be delivered to any WiFi connected device with display (like smartphones or tablets), after installing the NOTTV app.

[62] For regulating and creating a level playing field between television service providers, this convergence between traditionally separated markets should be considered when introducing MTV services. For more details see Section 7.

In such devices the additional cost for integrating an ISDB-T_{mm} receiver is relatively low. The estimated additional costs are not known as DoCoMo orders the ISDB-T_{mm} enabled handsets together with orders for their 'regular' mobile services.

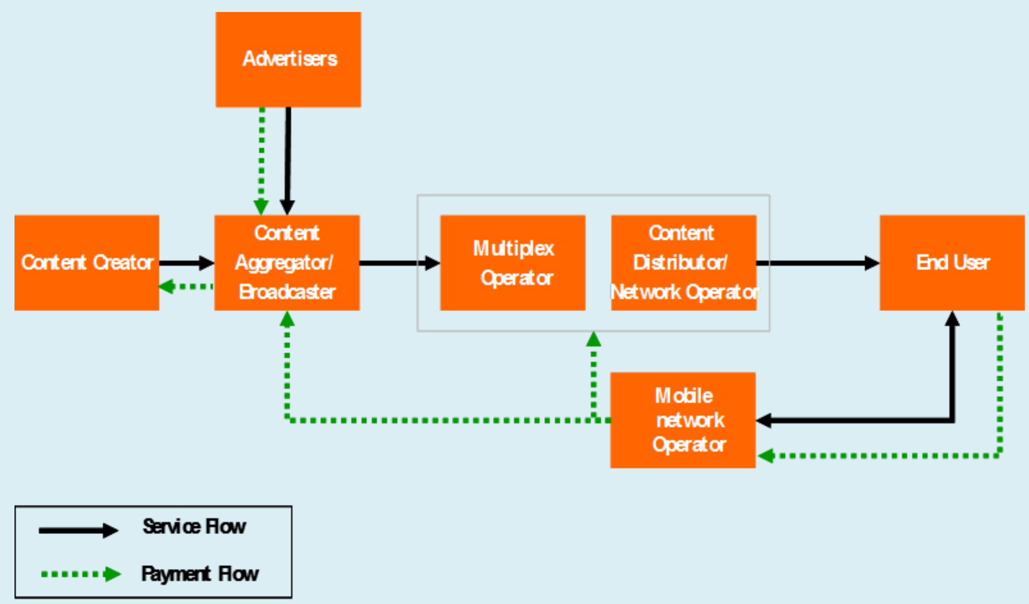
3.2.3 Business model and technology developments

This Section is split in three parts:

1. Business model;
2. ISDB-Tmm system developments;
3. NOTTV business developments.

Business model

As the ISDB-T_{mm}/NOTTV services are operated on a commercial basis it is important to consider its business model. The applied business model is fundamentally different from the model as applied in South Korea (see Figure 19). The model is a mixed model of pay and FTA services. Also the model is mobile operator led and is funded by a consortium of industry parties spanning across the broadcast and telecommunications industries. With reference to the ITU Guidelines[63], the corresponding business model is depicted in Figure 24.



Source: ITU

FIGURE 24: BUSINESS MODEL FOR MTV IN JAPAN

Figure 24 shows that the mobile network operator (DoCoMo) is leading the MTV service provisioning. The mobile network operator manages the end-relationship with customers on service provision,

[63] See ITU Guidelines on the Transition from Analogue to Digital Broadcasting, 2014 edition, see section 3.4.2.

marketing and customer care. For the MTV service, the mobile network operator (NOTTV) will need to purchase content from broadcasters and possibly other content providers. Based on an own MTV spectrum licence the mobile operator also plays the role of broadcast network operator (Japan Mobilecasting).

Customers will have access to an integrated service proposition (i.e. mobile phone and MTV services). The mobile network operator (DoCoMo) will receive service fee payments for the use of the MTV service from the end-user (i.e. subscription fees).

For the country visit it was learned that the business model was not passed break-even yet, after almost three years of operations and having 1.7m subscribers. This gives a good indication that the MTV business case is a challenging one, even when large parties like DoCoMo back this model. It was understood that before launching DoCoMo made a cost comparison between offering mobile television services on an LTE or ISDB-T_{mm} network. It was concluded that ISDB-T_{mm} was the better options given the projected number of subscribers.

ISDB-T_{mm} system developments

No recent developments can be reported in the further development of the ISDB-T_{mm} standard. On the website of the broadcast standardisation body in Japan (ARIB), only revisions of the 2010 enacted ISDB-T_{mm} standard can be found, including an extension of the system application scope from the VHF-High band to the VHF-Low band. Please note that NOTTV operates its network in the VHF-High band (207.5 MHz to 222 MHz).

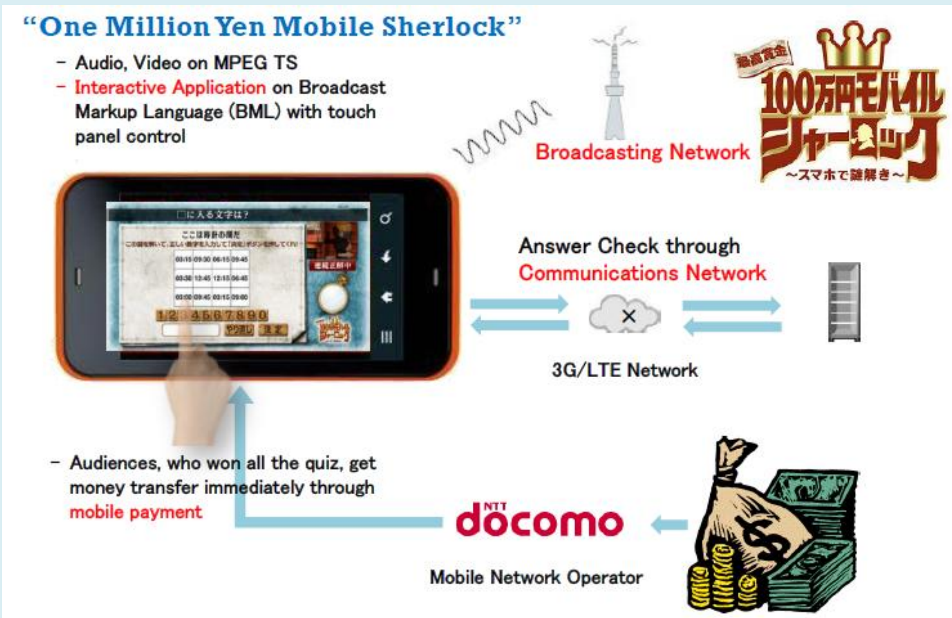
NOTTV business developments

NOTTV is continuing to expand its linear television content. This could demonstrate NOTTV's commitment to the platform as production and acquisition of linear television content is one of the most expensive forms of video content production. In 2014 its channel line-up was extended from 3 services to 4 services (of which two services are FTA and two paid services). In 2015 eight additional pay-tv services were added (see below). Figure 25 provides an overview of NOTTV's program guide.

Source: NOTTV

FIGURE 25: NOTTV'S PROGRAM GUIDE

In addition NOTTV develops interactive services directly related to its television broadcast services. These include services whereby the audience directly participates in for example a quiz show. Figure 26 shows NOTTV's "One Million Yen Mobile Sherlock" show.



Source: NOTTV

FIGURE 26: EXAMPLE OF AN INTERACTIVE TELEVISION SHOW OF NOTTV

The example in Figure 26 demonstrates the integration between the broadcast and telecommunications domain. Not only for the service delivery these domains are integrated, but also for the customer relationship processes; instant mobile payment through the mobile operator DoCoMo.

In April 2015 six new additional (pay-tv) channels were added to NOTTV channel line-up, they include[64]:

1. Fuji TV One (Sports & Variety by Fuji Television);
2. Fuji TV Two (Drama & Anime by Fuji Television);
3. Jidaigeki Channel (Historical drama by Nihon Eiga Satellite Broadcasting);
4. AXN (Hollywood titles by AXN Japan, part of Sony Pictures Entertainment)
5. Animax (Anime by Animax Broadcast, part of Sony Pictures Entertainment)
6. Sukasaka! (24hr Soccer Channel, by Sky Perfect Entertainment).

NOTTV bundles all this pay-tv services in a single package and charges approximately USD 5.30 per month.

3.3 DVB-T2 Lite

DVB-T2 Lite is defined as a specific profile for mobile reception conditions in the DVB-T2 standard (version 1.3.1 and up). It was designed so that only minimal changes were needed from existing DVB-T2 transmitters (modulator) and receivers (demodulator) to be able to support the new profile, which will encourage its adoption by equipment manufacturers.

It should be noted that with the DVB-T2 standard as applied in Thailand also mobile reception (see use case number 4 to 7 in Figure 3) is technically possible. With the use of Physical Layer Pipelines (PLP), which is an inherent feature of the DVB-T2 standard, different services can be broadcasted with different levels of robustness (code rate) and modulation schemes. Also the same service can be broadcasted over two or more PLPs, indented for different reception conditions (for example rooftop and mobile reception). Also time slicing (which can save battery life) can be achieved in the 'base' DVB-T2 standard. Even without the application of PLPs in-car reception is possible (see use case number 4 in Figure 3).

However for hand-held devices the receiver requirements are more demanding in terms of battery life, robustness and chip-set costs. Hence the DVB-T2 Lite profile was established, which includes the following key features:

1. Use of Future Extension Frames (FEF) as to allow for different FTT sizes (i.e. the number of carriers) between the base (DTTB) service and the mobile service[65];
2. Maximum bitrate of 4 Mbit/s;
3. Limitation of the number of the FFT sizes as to exclude 1K and 32K;
4. Prohibition of the use of rotated constellations in 256-QAM

[64] This was made possible by releasing an additional 6 MHz. After a call for proposal for using this additional spectrum six additional service providers were added to the MTV platform.

[65] In the 'base' DVB-T2 the different PLPs have to have the same FTT size.

5. Application of short FEC frames only;
6. Addition of two new even more robust code rates (1/3 and 2/5),
7. Halving of the size of the time-interleaver memory (as compared to base DVB-T2);
8. Limited number of permitted mode combinations.

All these technical measures are design to both reduce the complexity of the chip-set (hence the costs) and power consumption, and increase robustness of the signal.

3.3.1 Network implementations aspects

In 2011 and 2012 the DVB-T2 Lite profile has been tested, most notably by the BBC (UK) and RAI (Italy) with test transmissions. However to date DVB_T2 Lite is not in commercial operations yet. If implemented for commercial operations it is likely that DVB-T2 Lite will be initially implemented as an in-band system with the delivery of DTTB base services[66]. In this way (additional) investment levels in the network can be kept low.

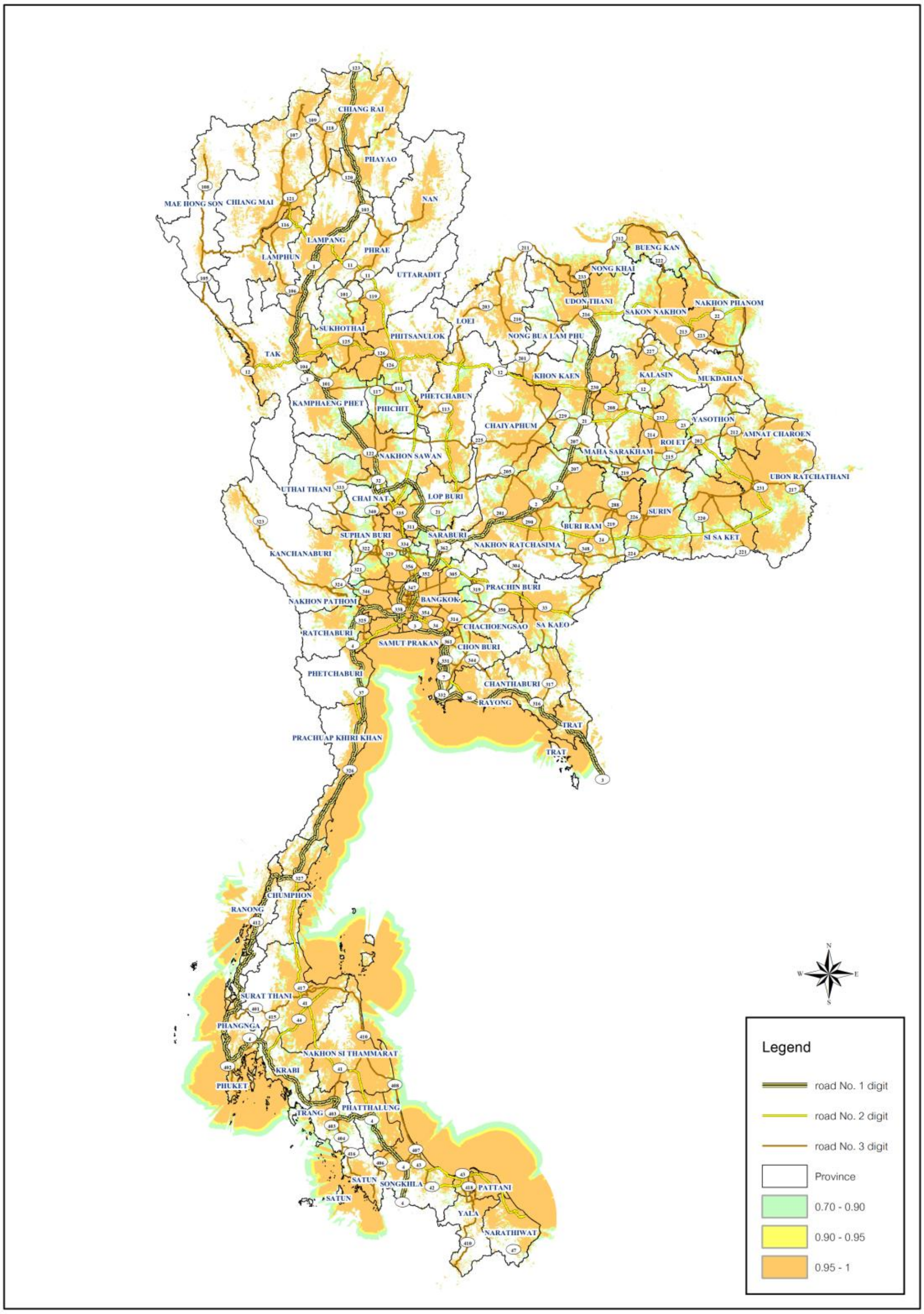
For Thailand having deployed a base DVB-T2 service, this would be an interesting option to keep open. However before applying DVB-T2 Lite it should be evaluated what the current network(s) can already deliver for the different use cases (as included in Figure 3).

Use case 4 (in-car reception)

The DTTB network with 171 transmitter sites[67], design for rooftop reception, already covers a significant part of the Thai roads and offers the possibility to receive the television services in cars (see use case number 4 in Figure 3) with the application of diversity antennas. Figure 27 shows the (noise limited) in-car reception areas and the road network in Thailand. It should be noted that this coverage can be delivered with the current network without the application of PLPs. More detailed maps can be found in Annex E: Detailed coverage maps for in-car reception.

[66] Some industry watchers argue the case that DVB-T2 Lite can also be used as a delivery platform for digital radio services. Its capacity would be larger than for any other digital radio system and receiver power consumption would be lower too. However to date no radio receivers are commercially available.

[67] See ITU report “Detailed planning of additional DTTB sites after ASO”, February 2015.



Source: ITU

FIGURE 27: DVB-T2 COVERAGE FOR IN-CAR RECEPTION AND MAIN ROADS IN THAILAND

The coverage as shown in Figure 27 corresponds with a total road coverage of 78.10 % which can be broken down as follows[68]:

1. Motorways (Thai roads with 1-digit number) have a total length of 3,733 kilometre and the DVB-T2 network covers 3,146 kilometre with in-car reception (84.24 %);
2. Main roads (Thai roads with 2-digit number) have a total length 4,483 kilometre and the DVB-T2 network covers 3,715 kilometre with in-car reception (82.00 %);
3. Roads (Thai roads with 3-digit number) have a total length of 11,904 kilometre and the DVB-T2 network covers 9,233 kilometre with in-car reception (77.56 %);
4. Sub-roads (Thai roads with 4-digit number) have a total length of 35,423 kilometre and the DVB-T2 network covers 23,793 kilometre with in-car reception (67.16 %).

Use case 5 and 7 (laptop and tablet)

For use cases number 5 (Tablet, see Figure 3), low power consumption and chip set costs may not be critical either (like in use case 4). In Thailand the local equipment manufacturer Samart supplies already tablets with a DVB-T2 receiver built in. Depending on the uptake of this type of receivers (and hence the demand for mobile television services), the number of transmitter sites of the current DVB-T2 rooftop network may have to be increased further (beyond the 171 planned sites) to offer more portable indoor reception, obviously needed for such type of devices.

ITU has assessed that for complying with NBTC's indoor coverage requirement (of providing indoor reception in 30 major municipalities), the number of sites should be increased[69]. Also for the Bangkok area (one of the major municipalities) 15 additional (small) stations were planned to improve indoor-coverage. Figure 28 shows a detailed map of the indoor coverage in the vicinity of Bangkok centre. The portable indoor coverage area is blue shaded and urban clutter areas are red shaded or dark blue if overlaid by the blue coverage area.

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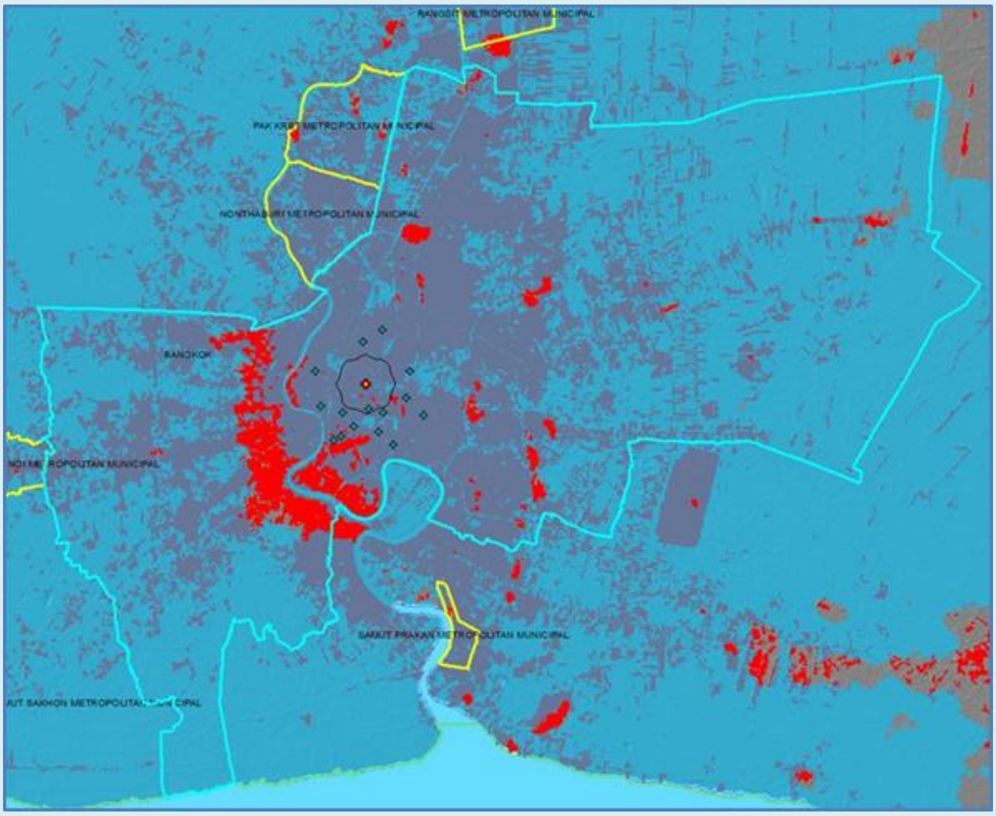
[68] Coverage areas with a coverage probability of 70% or more were included to calculate the road coverage in kilometres.

[69] See footnote



Source: ITU

FIGURE 28: PORTABLE INDOOR COVERAGE IN BANGKOK

Figure 28 shows that some parts of the Bangkok metropolitan area are not fully covered with portable-indoor reception, even with the application of the 15 additional sites (indicated with green markers). Although the overall percentage of households covered with portable indoor reception was calculated to be 43%, it should be assessed if such a coverage pattern, as shown for Bangkok, is marketable for mobile tablet use.

Marketers may assess that the coverage should be more uniform for mobile tablet use. A preliminary assessment (without having carried out coverage calculations) is that if such a requirement would be set, then this can be achieved with the following options:

1. Apply one or more PLPs in (one or more existing DVB-T2 multiplexes) for delivering the mobile services. The number of MTV services dependents on the applied modulation scheme and code rate in the PLP. This option will require that the existing base DVB-T2 services have to be carried in less capacity. Hence a reduction in picture quality, if the encoder efficiency is

not improved, has to be accepted. Balancing these factors is an iterative process what is generally referred to as the service trade-off[70];

2. Apply DVB-T2 Lite in FEF (in one or more existing DVB-T2 multiplexes) for delivering the mobile services. Again the number of MTV services will dependent on the applied FTT size, modulation scheme and code rate. Whether this option should be applied is also dependent on the results of the service trade-off in the first option. This second option gives more possibilities to be make the signal more robust and will reduce receiver requirements (in terms of costs and power consumption).

The option of increasing the number of sites is not included in the list of options. Such an option would imply that PLPs are not applied and no possibility of differentiating the services between the DVB-T2 base and mobile services. The work carried out for planning the rooftop and portable indoor coverage in Thailand, showed that for portable indoor reception the number of sites would increase significantly to get uniform coverage across large parts of Thailand. Hence this option is not proposed as a way forward in extending the mobile functionality of the existing DVB-T2 network.

Furthermore it likely that options one or two have to be combined with more additional transmitter sites. The combination of options one and two is not recommended as under such a scenario two different service areas would be created; one where DVB-T2 Lite receiver would be needed and another area where this receiver cannot be used (because the Lite service is not broadcasted).

Use case 7 (smartphone)

For a broadcast network able to deliver MTV services to a smartphone, the low power consumption and the low chip-set costs are prerequisite. Consequently for such a use scenario (MTV services delivered on smartphones the application of an MTV standard is needed, i.e. DVB-T2 Lite as addressed in this Section.

Even more so than use case 5 and 7 (laptop and tablet), the MTV network coverage should match the mobile 3G/4G network coverage. Hence the decision to offer MTV services to smartphones is a major decisions from the perspective of network investments. As the DTTB network investment increment will be large other alternatives should be considered as well. More specifically the deployment of LTE eMBMS over an existing LTE network. Besides a network investment decision such a MTV service introduction would also require the willingness of mobile operators and receiver manufacturers to participate and invest.

3.3.2 Technology & business developments

To date no commercial MTV services on the basis of DVB-T2 lite are offered. Without chip-sets and following that the production of receivers, a commercial introduction is not possible from a technical perspective. Recently chip-sets for DVB-T Lite have been developed and it is reported that a few manufacturers (Sony and Broadcom) are offering DVB-T2 Lite chip-sets (see also Section 3.3.3).

As this chip-set has low power consumption and allows very robust reception with a capacity of up to 4 Mbit/s (see Table 2), it is also proposed as a future transmission standard for digital radio. This

[70] For more details on the service trade-off see ITU guidelines on the transition from analogue to digital broadcasting, edition 2014, in section 4.3.1.

possibility of offering radio service over DVB-T Lite was also tested in field trials in the years 2011/12 (in Denmark). No commercial launch followed, likely due to the absence of mass produced receivers (or in other words the lack of willingness to invest under broadcasters, network operators and manufacturers).

3.3.3 Receiver availability and pricing

As indicated in the previous Section 3.3.2, Sony and Broadcom are reported to have DVB-T2 Lite chip-sets available. However mass produced DVB-T2 Lite receivers for either MTV or radio services are not available to date.

3.4 LTE

This section address the possibility of carrying live mobile television services over LTE eMBMS networks. In addition, it addresses the convergence between broadcast and LTE networks, the so-called tower overlay. This Section does not cover the implementation aspects of LTE networks as this is out of scope of this feasibility report.

3.4.1 LTE eMBMS functionality for live services

As covered in Section 2.2.4, LTE eMBMS allows the mobile operator to switch parts (a defined number of cells) of its network to broadcast mode for a specified duration (and can switch back to unicast mode after that broadcast period). It was suggested that a typical use case would include allocating one subframe to the broadcast services. Having 20 MHz bandwidth available, the eMBMS system could then make in the range of 5 Mbps available for broadcasting. Depending on the required picture quality a number of television services can be carried. For example when allocating 384 Kbps per services the eMBMS can carry approximately 12 -13 services.

Such flexible system functionality is typically designed for broadcasting television services around events (like football matches or music concerts), which take place during a limited period and in a specified/limited area of the network. Traditional television services are typically broadcasted 24/7 (see Section 1.2) and therefore the LTE eMBMS functionality is not comparable in this aspect to MTV systems[71]. However which functionality would be required is demand driven. The demand for different type of services, more specifically Video on Demand (VOD) and live/linear television (including 24/7) services is addressed in Chapter 5.

Other than technical considerations whether LTE can carry live television services, one could question if mobile operators would sacrifice unicast for broadcast traffic at a structural basis (as would be required for 24/7). Such a decision would be value driven.

Auctions around the world have demonstrated that the value for unicast services are very high. Recently auctions for assigning broadcast licenses have only taken place in Thailand. In this country

[71] The EBU studied the possibility of broadcasting FTA services over LTE eMBMS networks. It identified some other functionality differences around the FTA aspects. The implications of 24/7 or mass market broadcasting should be further investigated and more particular the delivery costs. A large scale TV distribution was not envisaged in the short term. See EBU TR 027, July 2014.

the bids showed that the price per MHz for broadcast spectrum was similar to mobile spectrum[72]. However with the sample size of one it cannot be concluded that broadcast spectrum is equally valuable to unicast spectrum. A large number of studies have demonstrated that the value for mobile/unicast services was much higher than for broadcast (and consequently spectrum was reallocated from broadcasting to mobile services – i.e. the digital dividend)[73]. In addition, the incentive auctions in the USA, where spectrum was not earmarked for either broadcasting or mobile services, showed that the value in mobile services was higher as telecommunications providers bid higher.

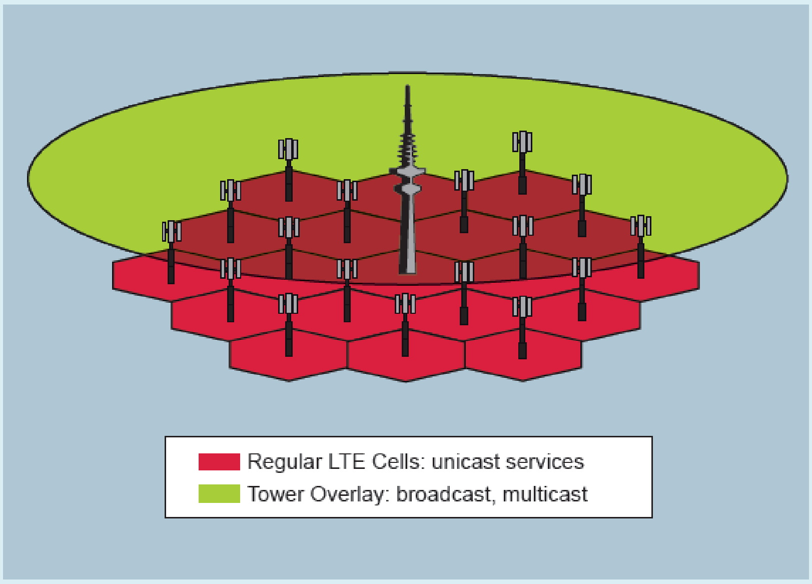
Consequently it would be very doubtful if mobile operators would switch their eMBMS network for large parts and long periods to broadcast mode.

3.4.2 Tower overlay

As explained in Section 3.3 the DVB-T2 system makes use of Future Extension Frames (FEF). In these frames any data can be carried. In Section 3.3 the frames were used to carry the DVB-T2 Lite data. In an alternative case these FEFs can be used to carry the data stream of the broadcast services in an LTE (eMBMS) network. The video or broadcast services are delivered over a typical DVB-T2 network with high powers and high towers. At the receiving end the services are received by devices which are LTE-A+ enabled (see Section 2.2.3) and logged in the cellular network of a mobile network operator, who is addressing all signalling. This converged system is called the 'tower overlay' and is depicted in Figure 29.

[72] See ITU report "Implementing Digital Terrestrial Television in Thailand", August 2014, in section 4.3.

[73] For example Analysys Mason report for the European Commission "Exploiting the digital dividend – European approach", August 2009 or CEG report for the GSMA "Licensing to support the mobile broadband revolution", May 2012.

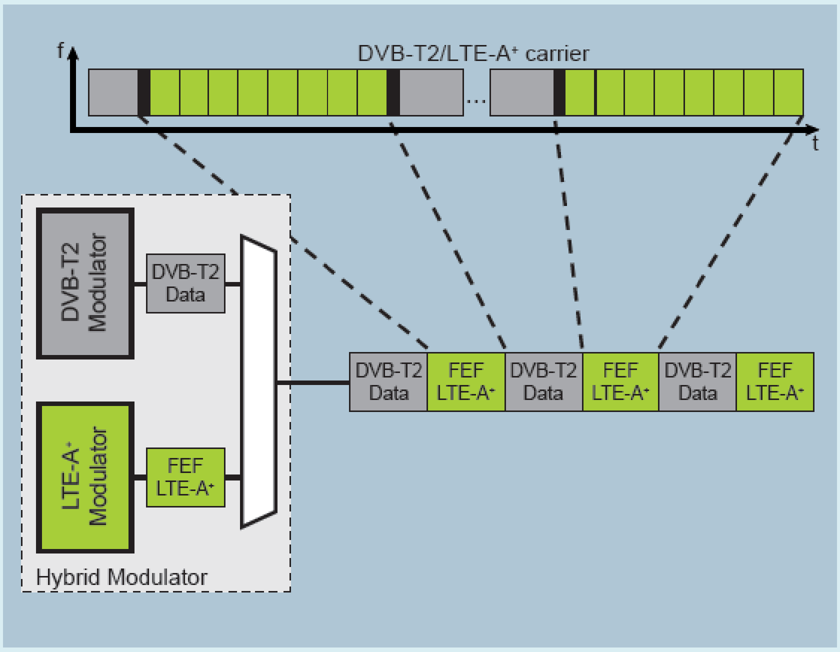


Source: Gatesair, TDF, Technische Universitat Braunschweig

FIGURE 29: THE TOWER OVERLAY CONCEPT

The advantage is that several network operators can share this DVB-T2 FEFs for delivering broadcast service without loading their networks with broadcast traffic. Consequently they will avoid sacrificing their unicast traffic. This solution works for event broadcasting but also for broadcast services intended for large coverage areas and for extended periods. For the latter case the high power high tower network topology of DVB-T2 works very efficiently (in terms of number of sites needed).

Like with the DVB-T2 Lite services (as explained in Section 3.3) the base DVB-T2 services can still be broadcasted in the same DVB-T2 network/multiplex; i.e. the tower overlay concept is in-band system. Figure 30 shows the concept of the in-band system, using the FEFs for the LTE broadcast services next to the frames for the base DVB-T2 services.



Source: Gatesair, TDF, Technische Universitat Braunschweig

FIGURE 30: THE IN-BAND SOLUTION

This tower overlay concept have been demonstrated to work in field tests. However some practical implementation aspects will have to be considered:

1. The mobile terminal needs to be LTE-A+ terminal, the plus sign indicating that it deviates from a 'standard' LTE-A handset. The difference likely to be software based differences. Although the differences will be small as compared to having an integrated MTV/LTE handset, manufacturers should be willing to produce these LTE-A + handsets. To date it is unknown whether manufacturers are planning to produce these handsets for the mass market;
2. For the concept to work in the most efficient way mobile operators should agree to share the FEF data capacity of the DVB-T2 network. Hence all mobile operators will deliver the same set of broadcast services. Hence there is no differentiator between the mobile network operators in terms of delivering broadcast services. Here again the added value of these broadcast services for a mobile operator needs to be addressed as to determine if this is a likely hurdle for sharing FEF capacity. A relatively low value for broadcast services (as compared to unicast traffic), as argued before, may point in the direction of a likelihood of mobile operators willing to share;
3. Although the signalling is all provided for in the LTE network, a mediation platform will be needed to make the mobile and broadcast network work together in synchronising their services (see Figure 6).

4. Current Thai TV & Mobile Market

This Chapter provides a concise overview of the current Thai television and mobile market. It provides insight into the local market specifics and is needed for assessing any current or future local market demand for mobile television services, regardless which technology will carry these services.

This Chapter is structured as follows:

1. Television market;
2. Mobile market.

4.1 Television market

This Section provides a comprehensive overview of the Thai television market. This Section will address the television market structure, market shares and offerings.

4.1.1 Market structure

The television broadcasting value chain can be broken down into six subsequent steps or functions in delivering television services to end consumer, i.e. the television viewer. Figure 31 shows these six functions.

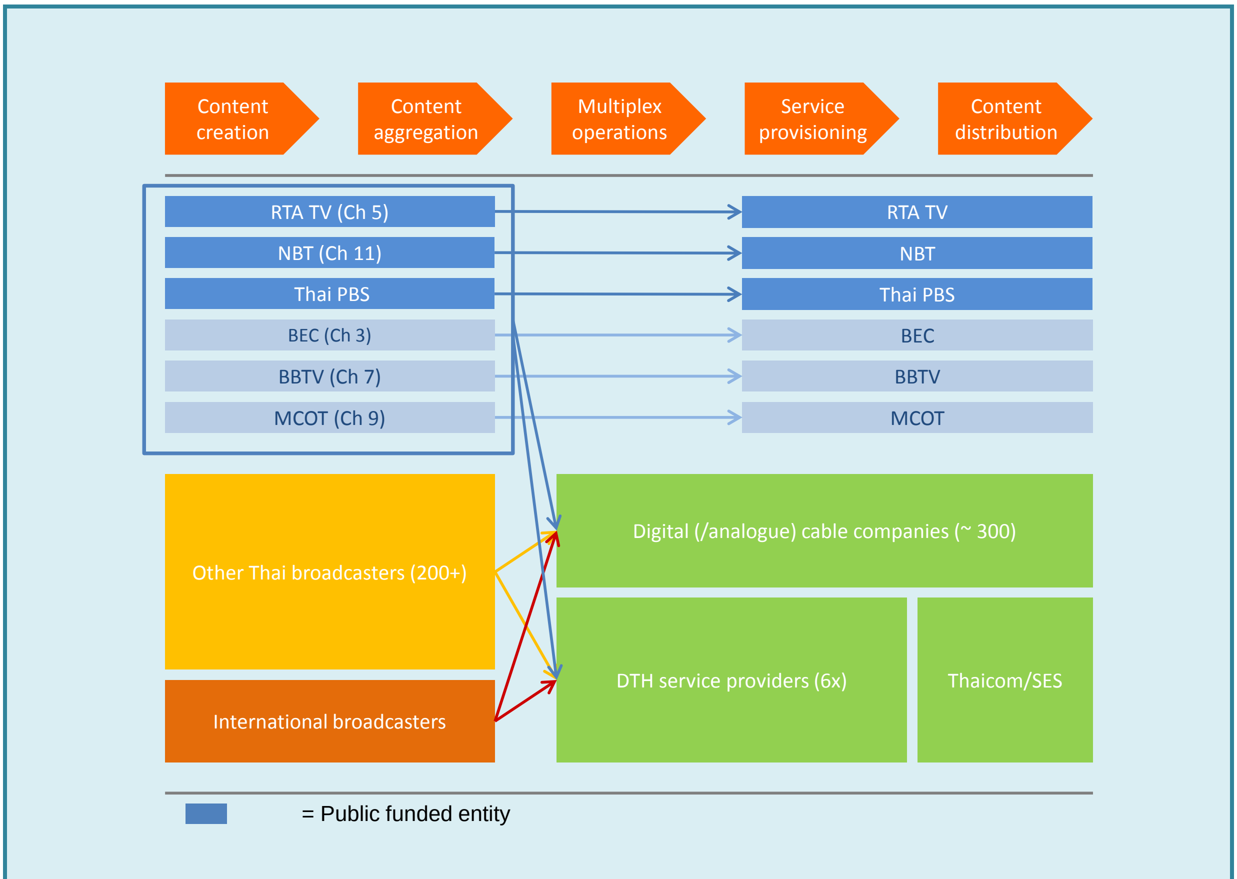
Content Creation	Content Aggregation	Multiplex Operations	Service Provisioning	Content Distribution	Reception
Create content and services	Aggregate content and service into customer oriented packages and service streams	Divide available spectrum in capacity units and allocate to (type of) services	Support or enhance the operations and marketing of content and services	Provide infrastructure or manage access to or delivery of the content	Provide decoding, navigation and interfacing equipment or software
	Manage advertisers, agencies and advertising space		Manage client relationship and invoice services		

Source: ITU

FIGURE 31: THE VALUE CHAIN FOR TELEVISION BROADCASTING

Figure 31 includes both the analogue and digital value chain. Compared to analogue television broadcasting the digital value chain has an extra function/player: the multiplex operator. By nature of the digital broadcast technology, where multiple programs or services can be carried on one frequency (i.e. multiplex), assigning the multiplex capacity to the various services is an extra function compared to the analogue broadcast value chain[74].

The Thai television market structure can be illustrated on the basis of the value chain as depicted in Figure 31. Until recently the Thai broadcast market mainly comprised analogue and digital platforms, including terrestrial, cable and satellite networks. Figure 32 shows the market situation before the introduction of DTTB, the uptake of broadband internet and smartphones.



Source: ITU

FIGURE 32: PAST MARKET STRUCTURE OF THAI TELEVISION SERVICES

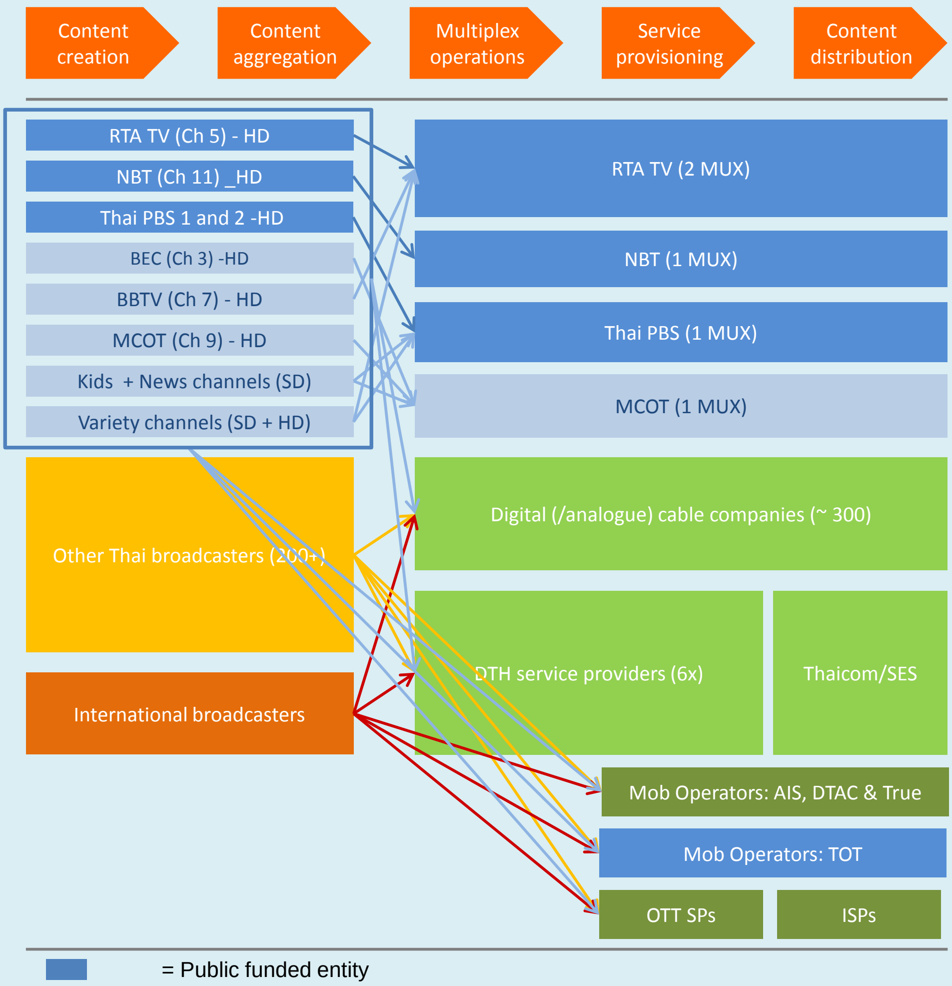
What can be observed from Figure 32 is the following:

1. The six incumbent terrestrial television broadcasters are vertically integrated companies. They cover all functions of the value chain, exempting the multiplexing function as this function is not included in the analogue broadcasting value chain;
2. The six incumbent broadcasters are present on all platforms, terrestrial, cable and satellite;
3. The large number of Thai broadcasters, next to the six incumbent broadcasters, which don't have access to the terrestrial platform;

[74] In the analogue value chain, each frequency can carry only one service (1-to-1 relationship) and the frequency license holder is very often the broadcaster. In the digital value chain the relationship is 1-to-N and the broadcaster is not necessarily the frequency license holder.

4. The six Direct-To-Home (DTH) satellite service providers which provide varying Free-To-Air (FTA) television service bouquets, as well as Set-Top-Boxes (STB) and installation services. They purchase satellite transponder capacity from satellite operators like Thaicom and SES New Skies.

As from 2012/13 the market started to change dramatically due to the introduction of new technologies, especially due to the launch of DTTB and broadband internet/smartphones services. In April 2014 four licensed DTTB network operators launched FTA digital services, including 24 new commercial television services. Also mobile operators start offering VOD and live television services, as well as Over-the-Top (OTT) service providers (both on fixed and mobile platforms)[75]. This new situation is depicted in Figure 33.



Source: ITU

FIGURE 33: RECENT MARKET STRUCTURE OF THAI TELEVISION SERVICES

[75] Examples are respectively DTAC's 'Watchever' services and OTT service provider 'TV Thailand'.

From Figure 33 the following can be observed:

1. Offering television services in HD quality is now the norm and a must have for future growth;
2. The number of DTTB multiplexes totals 5 at this stage of the network deployment. Although planned for, the sixth multiplex has not been assigned to a network operator yet. This sixth multiplex will carry the Community services[76];
3. The number of terrestrial broadcast services has increased considerably. From the six incumbent broadcast services it has increased to 27 at the launch of the DTTB platform and eventually to 48 when all services have been licensed[77];
4. All digital terrestrial services are made available on the satellite and cable platforms[78] and the Mobile operators start offering VOD and live television services in their data packages, as well as OTT service providers;
5. Other than Pay-TV services (like football or premium films), all television services are distributed on all available platforms and there is no content exclusivity for FTA services on any of the platforms.

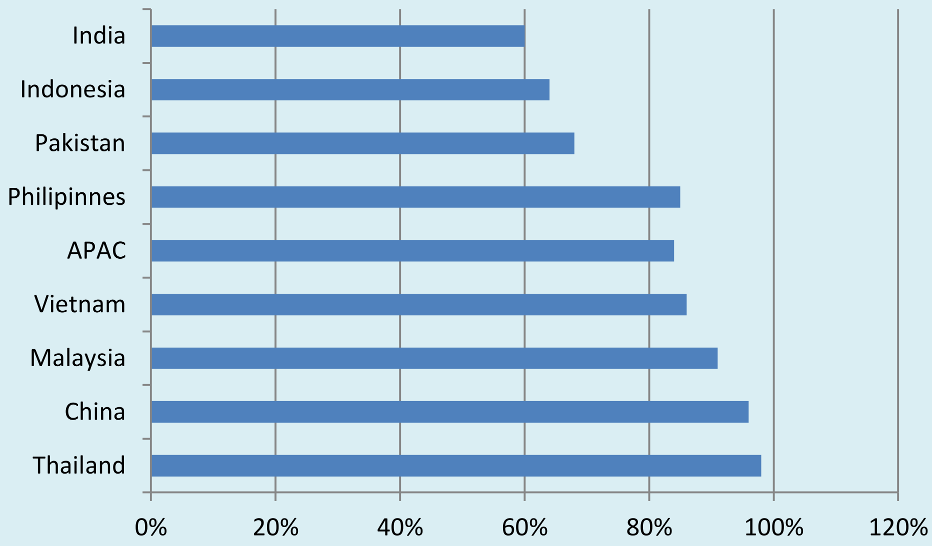
4.1.2 Market size and shares

The total population in Thailand is approximately 64.5 million with the total estimated number of households at 22.8 million. Television set penetration in Thai households stood in 2012 at 98% (see Figure 34) versus the Asia Pacific (APAC) average of 84%. Hence there are approximately 22.3 million television households (TVHH).

[76] Community services are non-commercial television services intended for serving local communities and 39 local community areas have been defined. In each local area 12 Community services will be made available.

[77] The number of 27 services comprises 3 Public Service Broadcasting (PSB) services, 3 Kids services in Standard Definition (SD) picture quality, 7 News services (SD), 7 Variety services (SD) and 7 Variety services in High Definition (HD). This number of 27 services will eventually increase to 48 services when more PSB and Community services will be assigned.

[78] The NBTC has required that licensed DTTB services providers will provide their service to cable and satellite platforms and that these cable and satellite service providers re-distribute the DTTB services with any charge (i.e. FTA).



Source: Credit Suisse

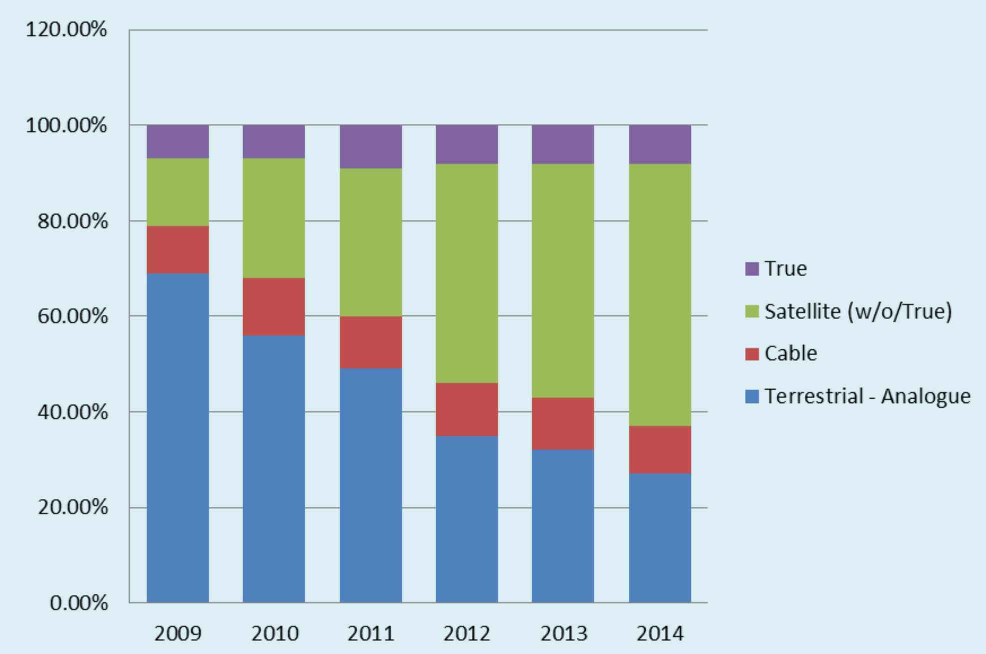
FIGURE 34: TV SET PENETRATION IN APAC COUNTRIES (IN %)

In the television industry market shares are often expressed in:

1. Number of viewers or subscribers, and;
2. Revenues per service and/or platform.

Revenues can be broken into three main categories per platform; (a) advertising revenues (which coincide with FTA broadcasting), (b) subscription of pay per event revenues and (c) line extensions which include revenues from program related events and merchandising. The latter group will not be considered in this report.

In Thailand the penetration of satellite and cable TV is growing fast while analogue terrestrial penetration is declining, as illustrated in Figure 35. It should be noted that this figure shows the situation just after the DTTB introduction in April 2014. Hence the number of TVHHs with DTTB are still very limited.

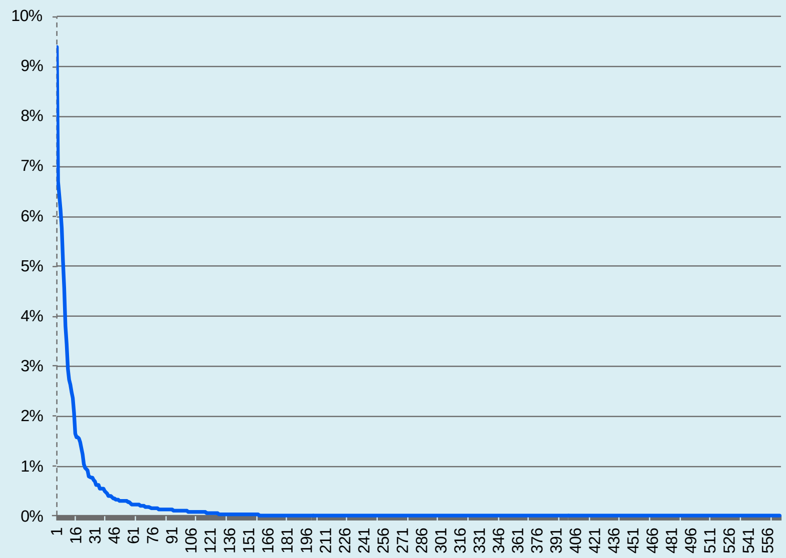


Source: AC Nielsen

FIGURE 35: NUMBER OF TVHH PER PLATFORM (%)

Before the DTTB launch and as can be observed from Figure 32 the six incumbent broadcasters were present on all television distribution platforms. This figure also shows the very high number of other Thai broadcasters (200+) present on selective satellite and cable networks. Figure 36 shows their viewing share on the satellite platform, excluding the six incumbent broadcasters. The figure illustrates the extreme 'long tail' character of the Thai television broadcast industry[79].

[79] The figure also includes international broadcasters. The top-20 includes all Thai broadcast services and they range from top-end 9.39% to bottom-end 1.37% viewing share.

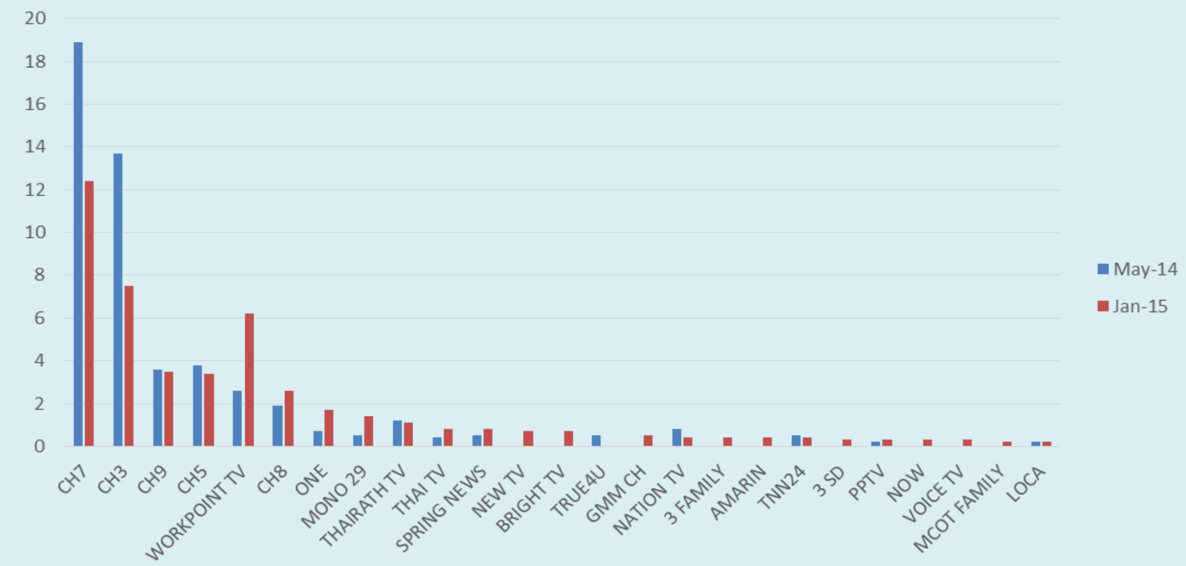


Source: AC Nielsen

FIGURE 36: VIEWING SHARES BETWEEN TV SERVICES ON THE SATELLITE PLATFORM

Four incumbent broadcasters have the majority all the television viewers; Channel 7, Channel 3, MCOT (Channel 9) and Army TV (Channel 5). The viewing ratings of the DTTB broadcasters just after the DTTB launch and half year after is shown in Figure 37. Due to the many new television services the viewing ratings of the four incumbent broadcasters have declined significantly[80]. Also like in Figure 36 the viewing ratings on the DTTB platform have the same 'long tail' shape.

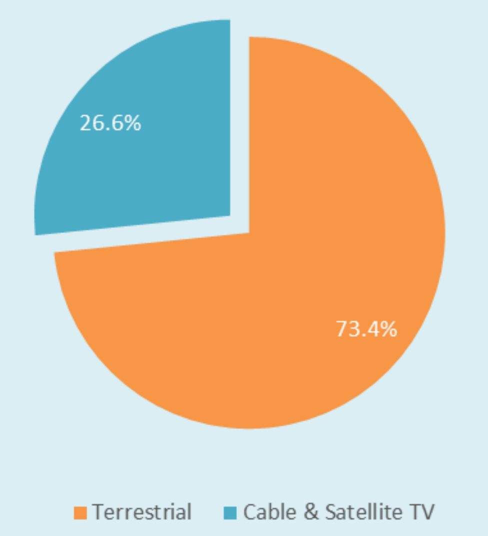
[80] Please note that Channel 3 and 7 operate their business on the basis of a concession (including the spectrum rights) awarded to them by respectively MCOT (Channel 9) and RTA (Channel 5).



Source: AC Nielsen

FIGURE 37: MAXIMUM VIEWING RATINGS IN MAY 2014 AND JANUARY 2015

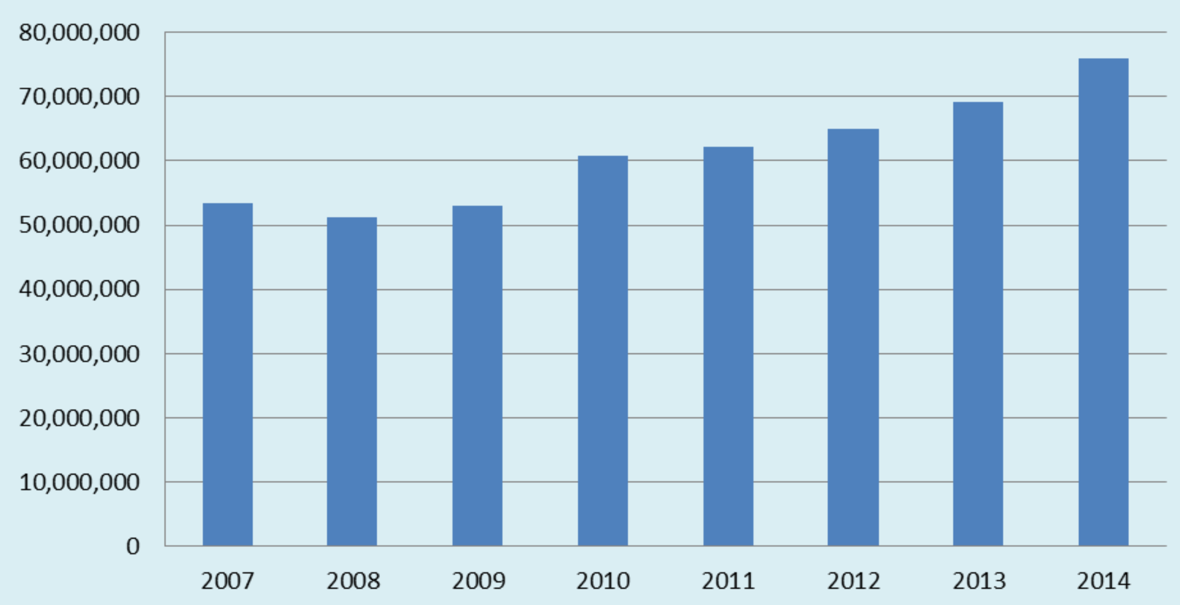
In Thailand television revenues comprise basically two sources; advertising income (on FTA platforms) and subscription fees for premium packages. The cable and satellite platforms both have Pay-tv packages on top of an extensive bouquet of FTA services. This FTA bouquet includes the six incumbent television services, attracting most viewing (see Figure 36 and Figure 37). Although the market share of the cable and satellite are growing rapidly (see Figure 35), most FTA viewing is still by far on the terrestrial platform, as shown in Figure 38.



Source: NBTC

FIGURE 38: FTA VIEWING PER TELEVISION PLATFORM (2014)

Like elsewhere in the world, TV advertising remained strong and growing at a steady pace over the years. Figure 39 shows the television advertising revenues over the period 2007 to 2014 with a CAGR of 4.5%.The total television advertising revenues stood at THB 76b (~ USD 2.3b) in 2014.



Source: NBTC

FIGURE 39: TV ADVERTISING REVENUES OVER THE YEARS (IN K THB)

Thai Pay-tv revenues range between THB 10-15b per year (~USD 0.29-0.35b). Cable television services are offered in the main cities. The average subscription fee ranges from USD 8 to 10/month for respectively an analogue bouquet of 80 services and a digital bouquet of 200 services (including the rental fee for the STB). Satellite premium packages are on average around THB 2,000 (~USD 60).

4.2 Mobile market

This Section provides a comprehensive overview of the Thai mobile market. This Section will address the mobile market structure, offerings and market shares.

4.2.1 Market structure

Like with the Television market (see Section 4.1), the Thai mobile market is undergoing significant change and is transitioning from a concession system to a more competitive market, where private companies can hold spectrum rights and operate their own network.

In the mobile telecommunications market, the key dominant players include Advanced Info Services Plc. (AIS), Digital Phone Co. Ltd. (DPC which is now part of AIS), Total Access Communications Plc. (DTAC) and True Move Co. Ltd. (True). These providers are still partly operating under Build Transfer Operate (BTO)[81] concession agreements with government-owned operators TOT and CAT, which have several others under their concessions as well. TOT and CAT are themselves also active in the mobile service market, although they hold very small market shares (see Section 4.2.2).

Before the Act "Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services B.E. 2553 (the Organization Act)" was enacted (and also the NBTC was established) TOT and CAT held the spectrum rights for respectively the 900/2100 MHz and 850/1800 MHz Band.

The auction of the 2100 MHz Band (also referred to as the 3G auction) in October 2012, marked the beginning of the transition process of the Thai mobile market. Table 5 shows the concessionaires and concession holders (TOT and CAT) prior to this 3G auction. Table 5 also shows the current use of this concession held spectrum.

TABLE 5: CONCESSIONS AND SPECTRUM USAGE

Concession Operator	Concession Holder	Concession Expiry Date	Spectrum Band	Current use
AIS	TOT	3/2015	900	2/3G, candidate band for 4G auction
DTAC	CAT	9/2018	800/1800	2/3G
DPC (now AIS)	CAT	9/2013	1800	In the process of migrating users[82], candidate band for 4G auction

[81] It should be noted that after the concessionaires are required to surrender their network assets on expiration of their BTO contracts. Hence the concessionaires will still depend on TOT and CAT infrastructure after these BTO contracts expire. The NBTC is in the process of finalizing transition arrangements.

[82] The NBTC has granted DPC/AIS and DTAC (extra) time to migrate users out of this band to respectively their 2/3G networks and other mobile operators.

Concession Operator	Concession Holder	Concession Expiry Date	Spectrum Band	Current use
True	CAT	9/2013	1800	In the process of migrating users, candidate band for 4G auction

In the 2012 3G auction spectrum rights where assigned to the three private operators (i.e. AIS, DTAC and True), by means of which they acquired their own spectrum rights and allowing them to operate their own network. Table 6 shows the spectrum assigned to these mobile operators and also the spectrum TOT holds in these bands, as well as current use.

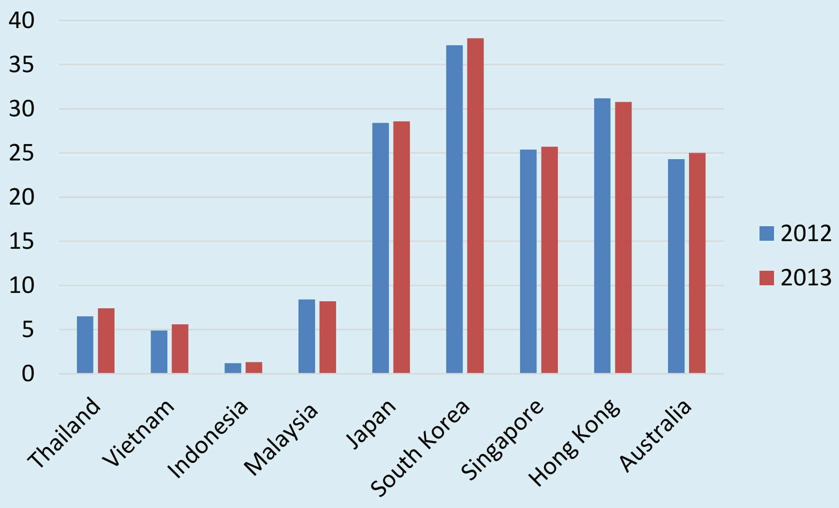
TABLE 6: ASSIGNED SPECTRUM IN 3G AUCTION AND CONCESSION HELD SPECTRUM

Spectrum holder	Number of Carriers	Up link	Down link	Current Use
AIS	3 x 15 MHz	1950 -1965 MHz	2140 -2155 MHz	3G + 4G trial
DTAC	3 x 15 MHz	1920 – 1935 MHz	2110 – 2125 MHz	3G + limited 4G deployment, using 5 MHz out of 15 MHz
True	3 x 15 MHz	1935 -1950 MHz	2125 – 2140 MHz	3G + limited 4G deployment, using 10 MHz out of 15 MHz
TOT	3 x 15 MHz	1965 – 1980 MHz	2155 – 2170 MHz	3G + plans for renting out 10 MHz unused spectrum for 4G

Table 5 and Table 6 show that users are migrated from the 1800 MHz Band and mobile operators have commence deploying 4G services, whilst sacrificing their capacity in the 2100 MHz Band. This may reveal a situation of (spectrum) supply side constraints. Especially considering, that the NBTC was in the process of preparing an auction for assigning the 1800 and 900 MHz Bands by September 2014 (referred to as the 4G auction). However the military coup of May 2014 put all preparations on hold. As today it is unknown when this 4G auction will take place.

Several indicators show that the mobile broadband services and smartphone phone penetration levels in Thailand are significantly below other countries in the Asia Pacific, like Japan and South Korea[83]. Figure 40shows the wireless broadband penetration in Thailand and selected Asia Pacific countries.

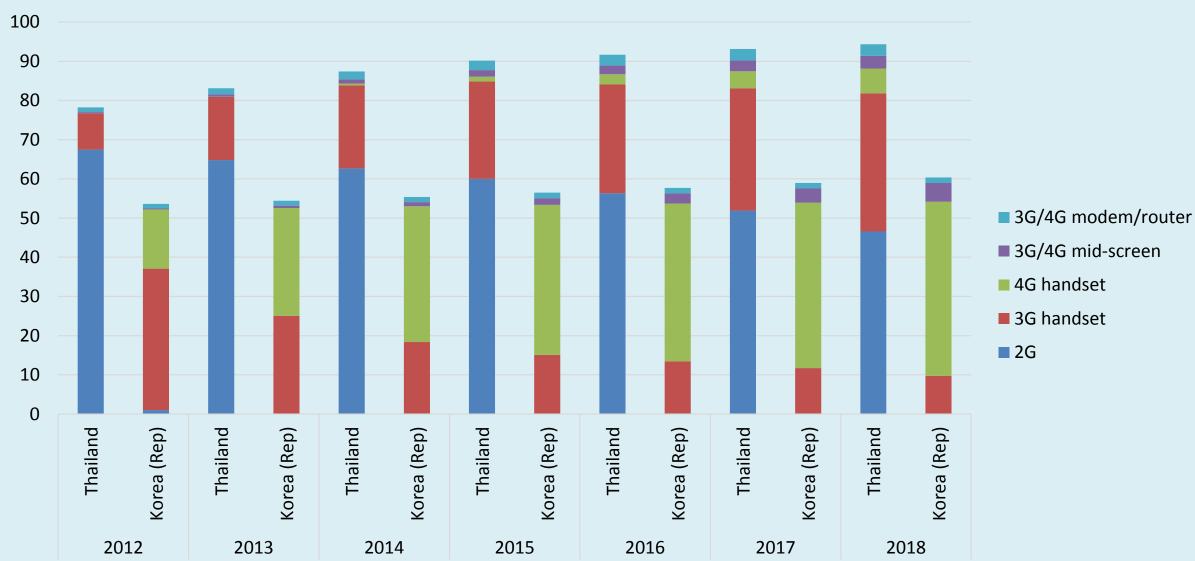
[83] See ITU report "Measuring the Information Society", 2014.



Source: ITU

FIGURE 40: MOBILE BROADBAND PENETRATION PER AP COUNTRY (PER 100 INHABITANTS)

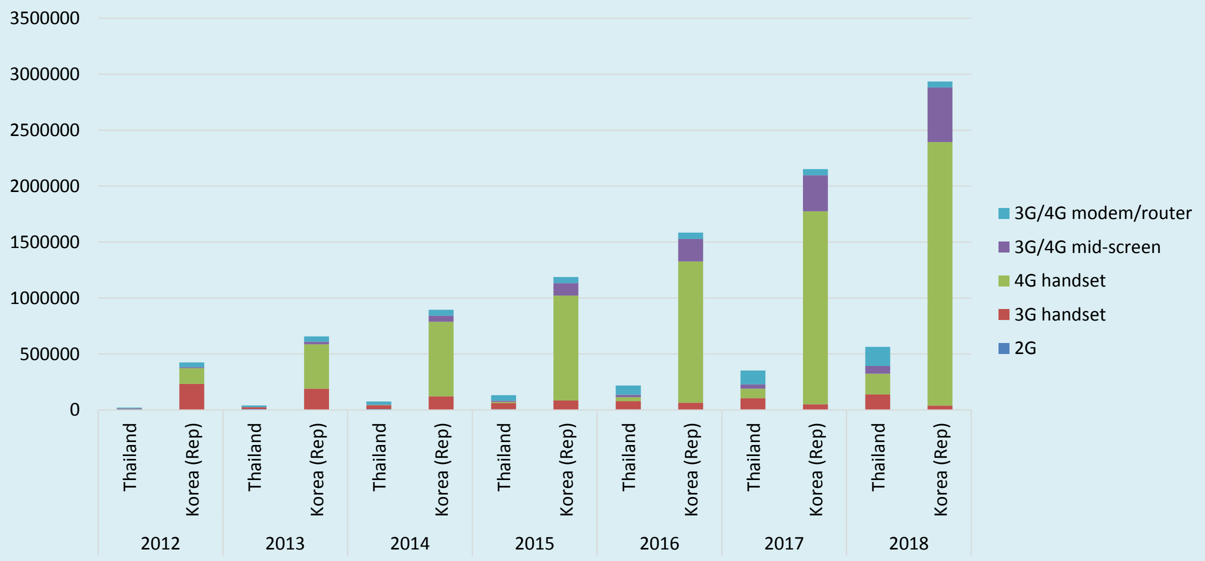
Forecasts for smartphone/tablet uptake and mobile data traffic show for Thailand a different composite than against South Korea as a benchmark. South Korea can be considered as an Asia Pacific leader in 4G and has a similar population size to Thailand. As Figure 41 shows, active mobile SIMs for 2G services remains a dominant proportion of all active SIMs. Whereas for South Korea the market is already dominated by 4 handsets as from 2014.



Source: Analysis Mason, November 2013

FIGURE 41: ACTIVE MOBILE SIMS BY DEVICE TYPE FOR THAILAND AND KOREA (REP)

Combining the results as shown in Table 5, Table 6 and Figure 41 explain the relatively low forecasted mobile data traffic levels for Thailand, again when compared to South Korea as market leader. Figure 42 shows the forecasted mobile data traffic for Thailand and South Korea. It should be note that this traffic includes mobile video as the key volume driver of mobile data traffic (see for more details on mobile video traffic Section 5.1).



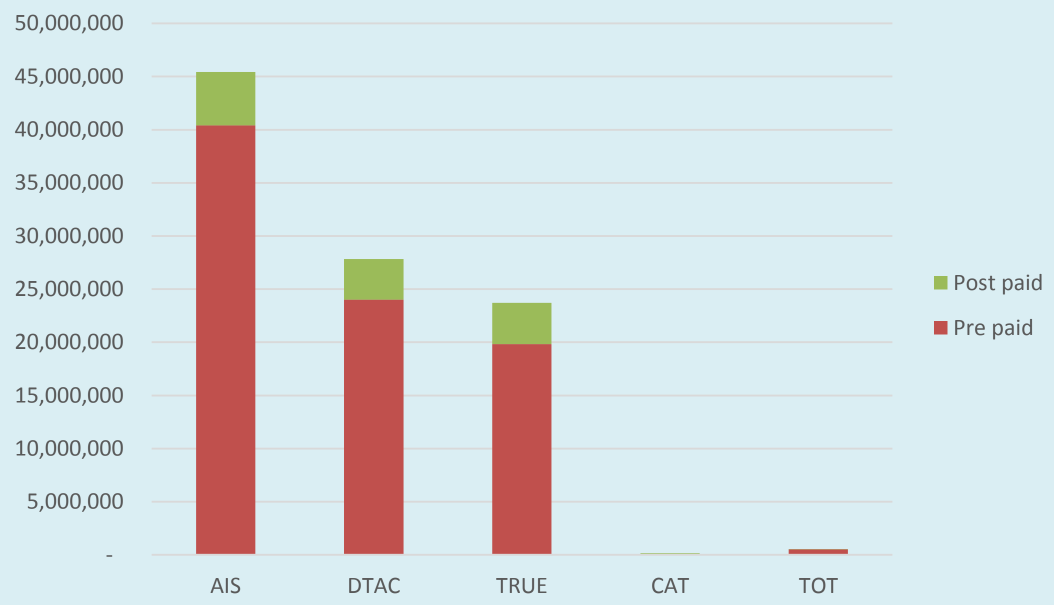
Source: Analysis Mason, November 2013

FIGURE 42: MOBILE DATA TRAFFIC PER DEVICE TYPE (IN TB)

4.2.2 Market size and shares

As stated in Section 4.2.1 the Thai mobile market is dominated by the three private mobile operators, AIS, DTAC and True. Figure 43 shows the total number of subscribers per mobile operator, clearly showing the lead of the private mobile operators[84]. Figure 43 also shows that the Thai mobile market is mainly a pre-paid market. Considering the total Thai population of approximately 65 million, it can also be observed that with a total subscriber base of approximately 98 million the mobile penetration stands above 145%.

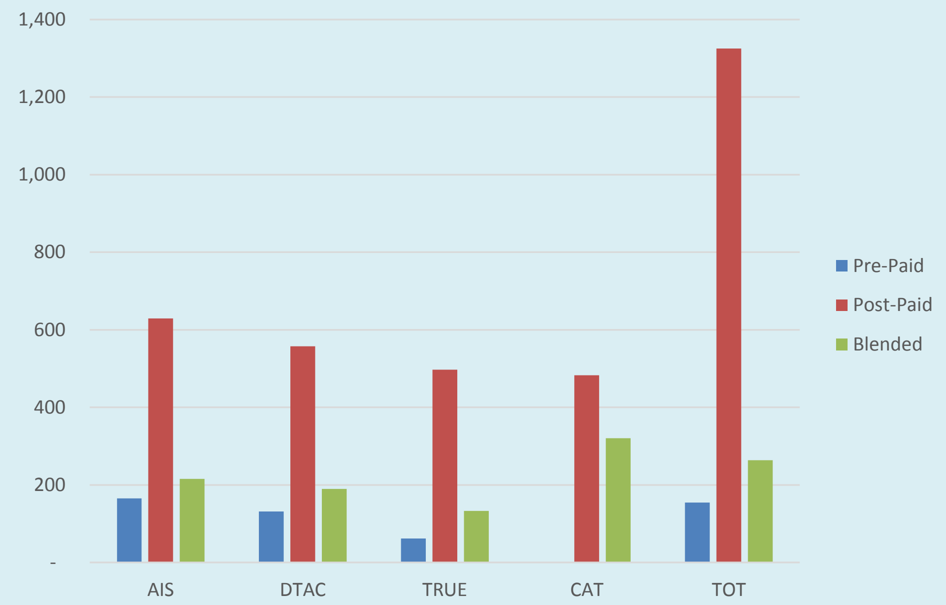
[84] AIS figures include the figures of Digital Phone Company Ltd. (DPC), holder of the 1800 MHz license and Advanced Wireless Network Co. Ltd. (AWN), holder of the 2100 MHz (3G) license.



Source: NBTC Q4 2014 estimates

FIGURE 43: NUMBER OF POST AND PREPAID SUBSCRIBERS PER MOBILE OPERATOR IN 2014

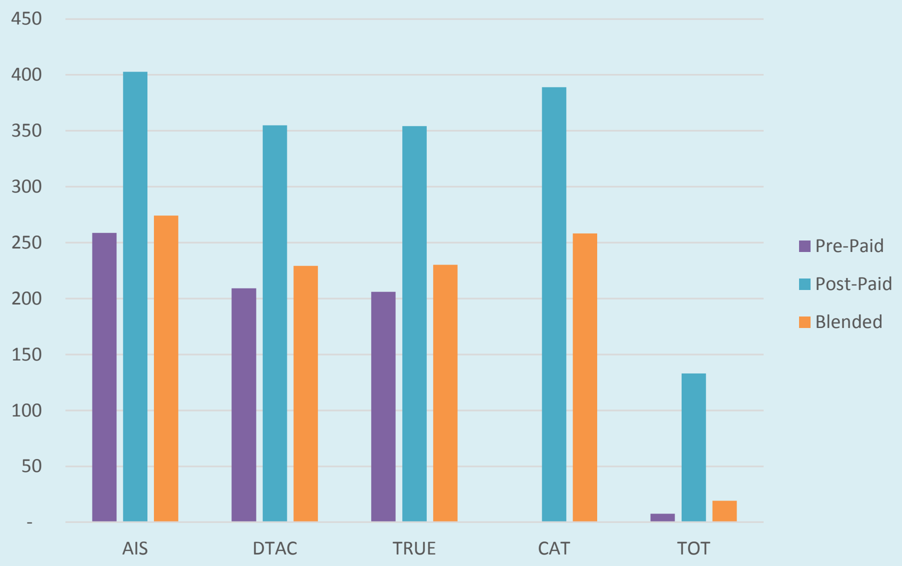
In Thailand the average revenue per mobile user is around USD 7 per month, compared with an average of USD 30 per user in the Asia-Pacific region. The post-paid market generates a higher Average Revenue per User (ARPU) as compared to pre-paid ARPU, for all operators, but cannot make up for the relatively low average ARPU. The only exemption seems to be TOT who has a significant different figure for ARPU, likely due to their business market customer base. Figure 44 shows the ARPU figures for the mobile operators in Thailand.



Source: NBTC Q4 2014 estimates

FIGURE 44: ARPU FOR POST AND PRE-PAID SUBSCRIBERS PER MOBILE OPERATOR IN 2014 (IN THB/MO)

The difference between post and pre-paid subscribers can easily be explained by a combination of higher charges in the post-paid market and higher average Minutes of Use (MOU). Figure 45 shows the average MOU per user (per month) for respectively post and pre-paid customers for all mobile network operators in Thailand.

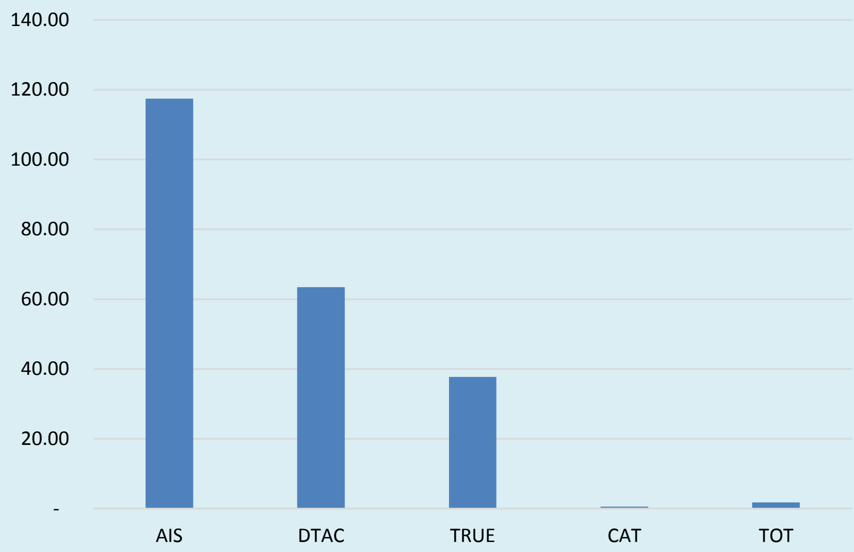


Source: NBTC Q4 2014 estimates

FIGURE 45: MOU FOR POST AND PRE-PAID SUBSCRIBERS PER MOBILE OPERATOR IN 2014 (IN MIN/MO)

The three private mobile operators all make part of a larger group with many subsidiaries, most notably AIS and True. AIS itself comprises many subsidiaries and is part of the In-Touch group which has holdings in Thaicom, the Thai satellite network operator. True's mobile business is part of the True holding company which comprise businesses for fixed broadband internet, cable and satellite television services.

Allocating revenues (and profits) to mobile-only activities is a complex matter. The blended ARPU figures (i.e. weighted average across pre- and post-paid subscribers) as presented in Figure 44 multiplied by the subscriber base (as included in Figure 43) give a good impression of the revenues the mobile operators generate from their mobile service business. Figure 46 shows the revenues of the three private mobile operators based on their reported ARPU and subscriber base.



Source: NBTC, adapted

FIGURE 46: REVENUES PER MOBILE OPERATOR (IN B THB)

5. Demand for Mobile VOD & Linear TV

This Chapter addresses the global market demand and trends for Video-on-Demand (VOD) and linear television services (also referred to as live video) on connected devices, in particular on mobile devices like smartphones and tables. It also covers the local demand for these services. As indicated in the Introduction a set of interviews was carried under relevant market parties in Thailand, including mobile operators, device manufactures and television companies.

This Chapter is structured as follows:

1. Global Demand for Mobile VOD and Linear TV;
2. Local Demand for Mobile VOD and Linear TV.

5.1 Global Demand for Mobile VOD and Linear TV

In this Section global demand for respectively mobile VOD and mobile linear television services is addressed.

5.1.1 Demand for mobile VOD services

The essence of VOD services is that viewers can select video content from a structured content library and have the content played out at a moment they like (see also Section 1.2). From a viewers' point of view it does not matter where this content is (partly) stored, either locally (in cached memory) or on a server in the network (i.e. in the 'cloud'), as long as the system response times are acceptable[85].

It is important to recognize the different type of VOD services. VOD services can be broken down into the following sub-categories:

1. Television and film services (like Netflix or Hulu);
2. Long form video clips, streamed or downloaded[86] (like catch-up television, including a full episode of a television program);
3. Short form video clips, streamed or downloaded (like YouTube).

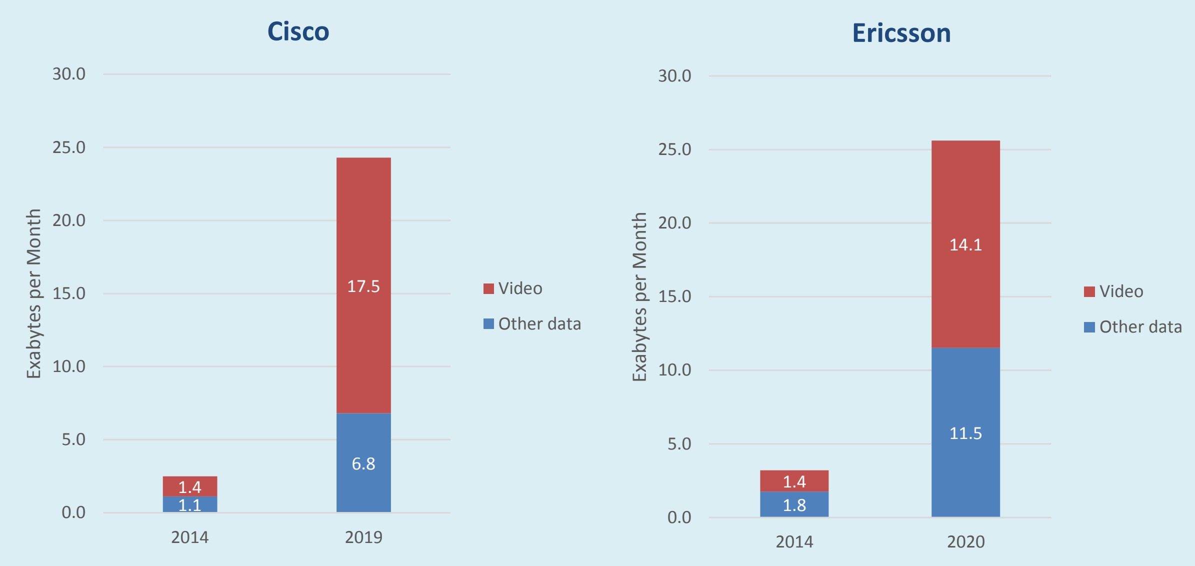
The global demand for VOD service is definitely on the rise across (fixed and) mobile networks. For mobile (cellular) networks the IP traffic is forecasted to increase sharply, driven by video and then mainly VOD. It is important to realize that video (streaming) traffic already comprises a significant

[85] A combination of local and network storage is possible too. A broadcast technology can be used to download the most popular content to local storage (on a hand-set). Less popular content can be requested over a switched network. A good example of this mixed system architecture is the NOTTV service in Japan which uses mobile broadcast technology (i.e. ISDB-T_{mm} standard) for file downloading. See also Section 3.2.

[86] From a consumer perspective streaming or (progressive/adaptive) downloading is mostly irrelevant as long as the viewing experience is the same. With downloaded content it is however possible to play back (part of) the content at a later time. Currently the difference between the two technologies is mainly driven by available network capacity and protection of content rights. It is expected that these differences will become less and less relevant in the future.

part of all current mobile data traffic, indicating that video traffic has an immediate impact on mobile data traffic today.

Figure 47 shows the 2014 actuals and 2019/20 forecasts for mobile video as a part of all mobile data traffic, as reported by Cisco and Ericsson in their periodical studies on global mobile traffic. It is important to note that these forecasts are essentially unconstrained traffic forecasts, i.e. they are not limited by (un)availability of network capacity[87].

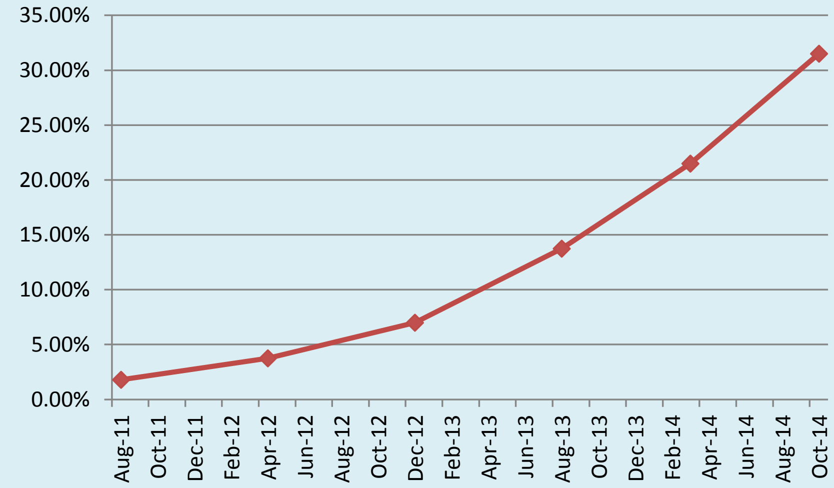


Source: Cisco VNI Global Mobile Data Forecasts 2014-2019, Ericsson Mobility Report, November 2014

FIGURE 47: MOBILE VIDEO TRAFFIC ACTUALS AND FORECASTS

As described by Cisco and Ericsson in their forecasts these mobile video traffic increases are for a large part determined by the current trend of more people having more connected smartphones and tablets. Figure 48 shows this global trend. Of all videos played on connected devices (i.e. desktops, smartphones, tablets and connected TV sets) the share of time played on mobiles and tablets combined, has risen to over 20% over the past 5 years.

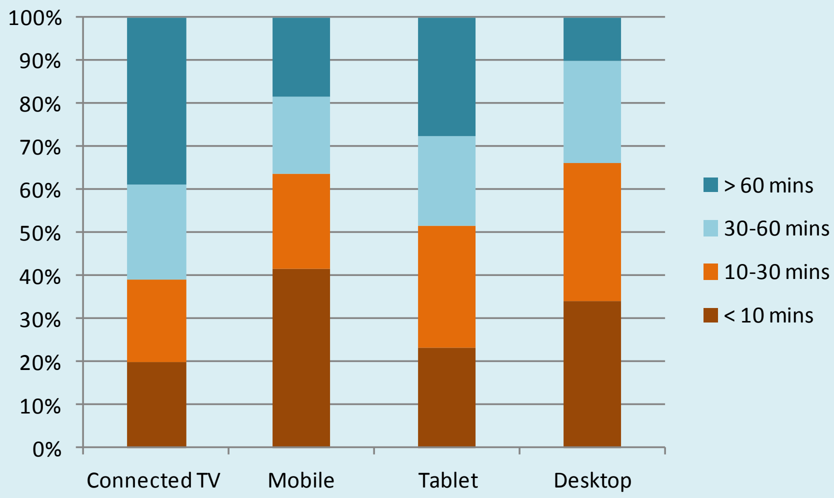
[87] See for example Plum report "Potential Benefits from sub-700 MHz spectrum in India", a report for the GSMA, dated January 2015.



Source: OOYALA Global Video Index Q3 2014

FIGURE 48: SHARE OF TIME PLAYED ON MOBILES AND TABLETS COMBINED, 2011-2014

This trend is also observed in the Asia Pacific region. However it is important to analyze the different categories of VOD played as it will help clarifying what consumers are consuming on their interactive mobile devices. Figure 49 shows the global figures for the share of time watched by device type (including also connected TV sets and desktop computers) and video length.



Source: OOYALA Global Video Index Q1 2014, adapted

FIGURE 49: SHARE OF TIME WATCHED BY DEVICE TYPE AND LENGTH OF VIDEO

Considering the categorization of long form video to include catch-up television (including an episode of 30 minutes or more), it is clear that connected television sets and tablets are mostly used for this type of video services. Mobile smartphones are more used for short form video although with the increasing screen sizes and processing power this type of connected devices move more and more towards tablet use. Figure 49 also shows that for television and film services (like Netflix and Hulu), having video lengths of over 60 minutes, the connected television sets is the key delivery platform.

5.1.2 Demand for Mobile Linear TV Services

For linear TV services the service provider schedules the audio-visual content, plays-out and distributes the audio-visual content according to the schedule (see also Section 1.2). Linear services are mostly distributed on the basis of 24 hours a day and 7 days a week (24/7).

The forecasts as shown in Figure 47 report on mobile video traffic and don't differentiate this traffic any further. The forecasts refer to applications such as YouTube and Netflix as example applications that drive this video traffic. Linear television services are not explicitly mentioned. However, linear television services are assumed to be included in these forecasts as mobile connected devices are already used for watching live services and thus should be included in the 2014 actuals. Of significant interest would be information on the proportion of mobile video content that is live, and the types of content which are viewed live on mobiles. There is a significant difference between consumers watching EPL/ECL finals on their mobiles and watching morning or evening news programming on them.

It could be argued that users having connected devices are watching linear television services (mainly) by means of a Wi-Fi network at home. This happens and is an important factor to be considered in forecasting mobile video traffic. However it is understood from the Cisco forecast that traffic off-loading volumes are not included in the mobile data traffic forecast as included Figure 47[88].

The question remains how much of this (mobile) video traffic contains linear television of live video. This is an important question to address as live mobile video content is most efficiently distributed over MTV/broadcast technology (see Section 3.4), whereas VOD services require a two-way medium like LTE. A second and important question is what the characteristics of mobile user demand for live video traffic are. If MTV is based on 24/7 service delivery but demand is only meaningful at peak times, or for premium content, then MTV may not be the most efficient use of spectrum, even if it is the most technically efficient means of distributing linear content.

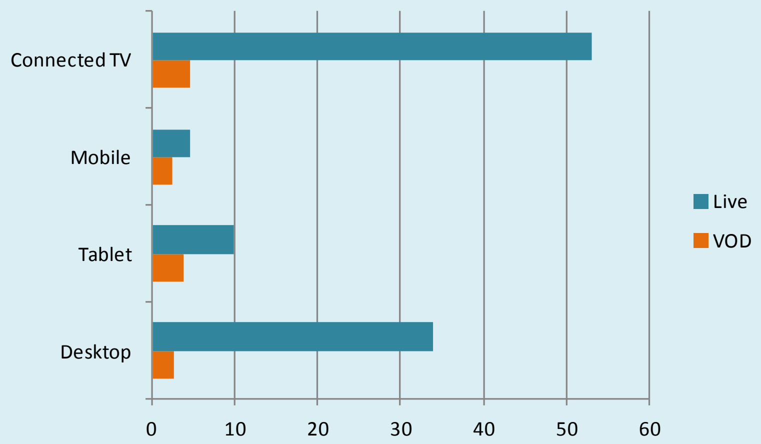
There is no hard global or local data available on how much percent of total mobile video traffic is live video (versus VOD). From interviews with Thai mobile operators (see Section 5.2) it was understood that although they offer live video/television services (see for example Watchever from DTAC) the fast majority of video traffic was consumed for catch-up television. For missed episodes of popular mainstream television soaps, mobile video users stream the missed episode to their handheld (i.e. VOD). Traffic volumes for mobile video were still limited due to the relatively low penetration rate of smartphones and the data-packages offered. Watching video is relative expensive as it eats up data quickly.

This raises two issues. Firstly, MTV services require not just smart-phones, but specific phones which are MTV enabled. Secondly, Thailand appears to have lower volumes of mobile video traffic than its

[88] Compare figure 1 'Global Mobile Data Traffic, 2014 to 2019 and figure 17 'Percentage of Mobile Traffic to be Offloaded, in Cisco's VNI Global Mobile Data Forecast 2014-2019.

market size would otherwise suggest. Launch of a commercially viable MTV service would require a significant increase in smartphone penetration and that this increase involves mostly MTV-capable devices. Secondly, it would require a shift in Thai demand for video content away from catch-up television towards linear viewing on a mobile. In effect it would require consumers to swap to watching a soap in its designated airing slot via their phone, as opposed to using their phone as a convenient device for catching up on shows they could not see during their first run.

However there is global evidence that live video is consumed over mobile networks and could potentially have a large impact on mobile networks as live video is watched considerably longer per session than for VOD. Figure 50 shows the global figures of the average watching time of live content per session compared to VOD per session.



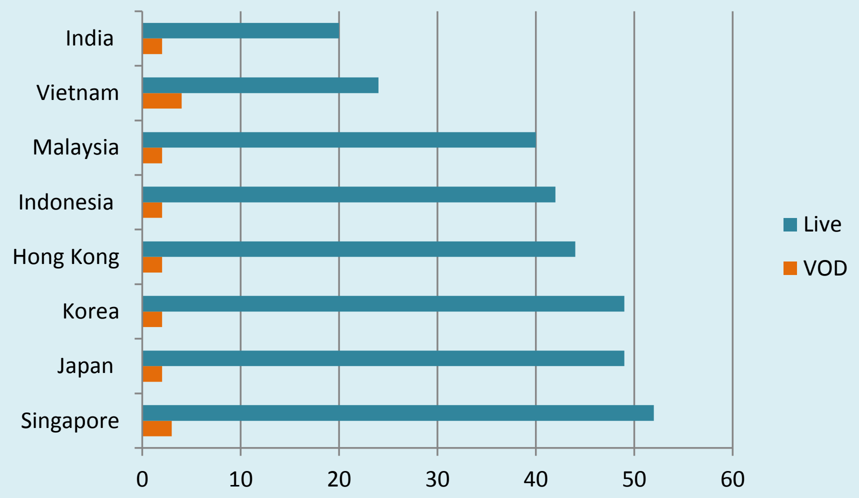
Source: OOYALA Global Video Index Q1 2014

FIGURE 50: AVERAGE WATCHING TIME (IN MINUTES) PER TYPE OF CONTENT

Figure 50 clearly shows that the attention span of viewers (or customer retention) is much longer for live content than for VOD type of services, although the effect is much less pronounced on mobiles. On connect TV sets the ratio live/VOD is over 10, whereas for mobiles and tables it is about 2[89]. While the figures for desktop or connected TV viewing indicate a massive difference in viewing time for live rather than VOD content, the same is not the case for mobile. Average viewing times for video on mobile devices is less than five minutes regardless of whether it is live or VOD content. The longer viewing time for live content is unlikely to generate more traffic than for VOD content as the number of sessions for VOD is likely to be much higher.

Figure 51 shows the average watching time of live content per session compared to VOD per session for 8 selected Asia Pacific countries.

[89] This also reflects that the implied advertising value around live content could be larger than for VOD.



Source: OOYALA Global Video Index Q1 2013, adapted

FIGURE 51: AVERAGE WATCHING TIME (IN MINUTES) PER TYPE OF CONTENT IN SELECTED AP COUNTRIES

As can be observed from Figure 51, for the Asia Pacific region the live/VOD ratio is significantly higher for countries like Singapore, Hong Kong, Japan and Korea. The live/VOD ratio in these countries is over 20. This is likely to be explained by the high penetration and good quality fixed and mobile broadband in these countries[90]. With the widespread availability of (mobile) broadband and having high performance smartphones/tablets, live video may become larger in its relative contribution to the total level of mobile video traffic.

5.2 Local Demand for Mobile VOD and Linear TV

From interviews with local market parties (i.e. broadcasters, mobile operators and device manufacturers) operating on the Thai mobile and television markets the following could be observed:

1. Parties were unaware of MTV systems and their functionality for delivering television services on handheld terminals. LTE and LTE eMBMS were generally known as systems for delivering mobile video services;
2. After explanation of the MTV and LTE eMBMS functionality, the differences and handset requirements, they assessed the necessity of having an MTV system as small, for both the short and longer term. This was supported with the argument that LTE investments will be carried out first, before introducing any other system. As observed in Section 4.2 Thai mobile operators have just started deploying LTE networks. Hence any future investments in MTV systems cannot be expected in next two to three years;

[90] See ITU report "Measuring the Information Society", 2014.

3. Although live television services were offered on their mobile platforms, their actual usage was low as compared to the VOD services. The most popular VOD service was the 'catch-up' service of popular soaps. Also live TV watching was limited by the fact that it consumes a large part of the data bundle quickly (this is in line with the findings in Section 5.1.2);
4. It was not evident that offering live television services was a 'must have' service as the traffic volumes associated with this type of service were (still) low. Consequently the costs of offering live television services was low in terms of network capacity (and also in terms of content costs as they offered FTA services, already streamed over the Internet). Live television services could therefore just be nice-to-have services (as costs are currently low);
5. Consequently it was not clear if a MTV network could serve the purpose of off-loading traffic from LTE networks, in the future when video volumes will go up (what is in line with what was concluded in Section 5.1.2 that future demand for live video is not clear at best and not likely to be large in the near future). Or in other words only must-have services could lead to such a necessity for traffic off-loading.

From the above local observations it can be concluded that the Thai demand and trends do not substantially differ from globally observed consumer demands and trends, as described in the previous Section 5.1.

5.3 Further analysis of demand

In the Section a further analysis is carried out on the demand for linear television services on mobile devices, regardless whether they are delivery by means of MTV or LTE systems. It also address the handset requirements for delivering these services.

5.3.1 Spiky demand for linear mobile television services

As MTV is a 24/7 broadcast service, a reservation makes sense if demand for live content is also 24/7. It seems more likely that demand for live content via mobile devices coincides with the (short-term) existence of "must see" live content. Examples of such content would be major sporting events, such as EPL/ECL/Olympic finals, or major news stories. Viewers place a significantly greater premium on seeing this content live than they do on seeing regular television programming "live".

This indicates that demand for live/linear content on mobiles is likely to experience significant peaks and troughs, with significant demand when must see content is available and far less demand at other times. Critically, the existence of demand for linear content on mobiles at peak times does not mean that there is sufficient demand for live content in general to warrant an MTV spectrum reservation. Unless this spectrum reservation comes with a very low spectrum claim (like with in-band systems). In short, if there is not sufficient 24/7 demand for linear video on mobiles, the existence of demand at peak times may not make an MTV service viable (and ultimately market parties should assess such viability).

Where demand for linear content spikes and then dissipates the capability of LTE EMBMS to dynamically assign spectrum to either broadcast or unicast mode is likely to be more effective at meeting consumer demand overall. However mass market delivery of live events (i.e. large proportions of the populations and nationwide service availability) may still require broadcast systems (see for example the tower overlay concept in Section 3.4.2).

Hence, while it is clear that there is some demand for live video content on mobile devices the nature of this demand plays a critical role in determining whether a reservation for MTV would be the best use of radiofrequency spectrum in Thailand.

5.3.2 Distinct demand for linear video services on mobiles

As noted in Section 5.1, there is some demand for linear video content on mobiles. What is not clear is whether this is distinct demand for the content *on mobiles*, or whether it is more accurately categorised as a subset of demand for premium content. If consumers demand the particular content and are indifferent as to how they access it, i.e. they chose mobile based on convenience at the time rather than a specific preference, it is unlikely that there will be sufficient demand specifically for mobile linear video content. For example significant demand for live viewing of the World Cup 2014 on mobiles is unlikely to relate to demand for mobile content so much as demand for viewing World Cup matches live rather than on catch-up.

This raises further issues, in particular what content would be available in Thailand and what impact would this have on demand for a linear mobile video service. Demand for such services in Thailand is likely to be substantially dependant on whether or not it carries premium content. Where exclusive licenses for premium content are already held, as is usually the case, it should be considered whether there is still room for other premium content for linear mobile video services.

Hence with the current market data available and the assessment that demand for linear mobile video services will be relatively small in the short term, the costs for keeping an option open for any service introduction should be small, whether it is on the basis of LTE or MTV systems.

5.3.3 Handset requirements

One of the most critical issue with the use of MTV systems is that it requires dedicated hardware in end-user devices. This can be contrasted with LTE-eMBMS, which only requires software alteration to existing LTE-A devices. This effectively means that the possible market for commercial MTV services is limited to users who have an MTV-enabled handset. At present phones which are MTV-enabled are relatively rare globally, and extremely rare in Thailand. Compounding this issue is Thailand's low rate of smartphone penetration generally.

In order for MTV to be commercially viable in Thailand there would need to be significant growth in smartphone penetration, and this growth would have to be significantly comprised of phones which are MTV capable. Prima facie this combination is unlikely to occur in the short-to-medium term.

6. Future scenarios

This Chapter addresses whether there is a future role for MTV systems in the Thai market for mobile video services, given the available technologies (see Chapter 2 and 3), the Thai market structure for television and mobile services (see Chapter 4), global demand for mobile video services, as well as current local demand (see Chapter 5).

It assesses if there are any likely future scenarios under which MTV systems are needed. If deemed likely, the national spectrum manager (NBTC) is faced with the question whether it should reserve spectrum for MTV systems. If deemed unlikely, the national spectrum manager should consider alternative allocations for this spectrum. These spectrum considerations are addressed in the next Chapter.

As set out in Chapter 5 it is not clear to what extent there is demand for linear television services on hand-held devices in Thailand. While is clear that both globally and in Thailand there is significant demand for VOD content it is unclear to what extent this applies to linear video content. Significantly clearer evidence of demand for a linear services, as opposed to any video content delivery service, would be needed in order to justify reserving spectrum for allocation an MTV service. In particular, there would need to be demand for a 24/7 model of linear broadcasting, as opposed to demand for specific premium live content at peak times.

In addition to the technical model to be used for a service launch, a viable commercial model would be needed. At present it is not clear that such a model could be developed for the Thai market, and evidence that it could should be presented before any spectrum is set aside.

6.1 Matching content demand with technology characteristics

As Chapters 2 and 3 highlight MTV and LTE-eMBMS are suited to fundamentally different forms of content delivery. MTV is suited to 24/7 nationwide delivery of linear content. In contrast, LTE-eMBMS is suited to peak-demand delivery of specific content (in smaller areas) more efficiently than unicast LTE services are able to.

Whether an MTV service is commercially feasible depends on whether or not there is demand in Thailand for 24/7 delivery of linear content to mobile devices. More specifically there would need to be a level of demand sufficient to make the service commercially viable and which justified a reservation of (valuable) radio spectrum for this use. This would for example imply the reservation of a nationwide multiplex for MTV services. This multiplex can then only be used for MTV services (either in VHF Band III and/or UHF Band IV/V). Or in other words, DTTB or digital radio services are denied access to this spectrum. Only an in-band reservation seems to be justified as the spectrum claim is little/flexible and the cost for keeping it open low (as DTTB is already deployed and 6 multiplexes are reserved in the national spectrum plan of Thailand).

Furthermore an in-band reservation, and the NBTC allowing such an alternative use, would provide the DTTB providers an option to further improve their business case if there would be demand for linear television services on mobile devices in the future. As described in Section 3.3.1, such a business case improvement is beyond the possibility of delivering mobile services to cars (see the use cases in Section 1.2) as the current DTTB networks can already deliver such functionality.

On the other hand, LTE-eMBMS does not require a constant or even consistent level of demand in order to be viable or useful. One of its main advantages is the ability to dynamically assign spectrum between broadcast and unicast usage. Even if spikes in demand for specific linear content only occurred every few months an LTE EMBMS enabled network would not have spectrum sitting idle in between these periods, as it is assumed that demand for unicast services will continue to outstrip the available capacity in the deployed LTE networks.

As outlined previously it is more likely that demand for live video content on mobile devices would coincide with peaks in demand caused by the availability of specifically desirable content such as major sporting or news events. If this is in fact the case then LTE-eMBMS gives a better technological fit to demand characteristics, as it can scale up and down the amount of spectrum used for broadcasting in response to increases and decreases in demand.

6.2 Scenario for a spectrum carve-out for a MTV multiplex

There is no single specific scenario in which a reservation of spectrum for a MTV multiplex makes sense in Thailand. Rather there are a series of requirements which would need to be met in order for such a reservation to be justified. This is especially the case given that UHF spectrum suitable for MTV is in high demand for LTE deployments and DTTB HD services. To justify reserving this spectrum for an MTV multiplex, all of the following would need to be the case:

1. There is significant demand for video content on mobiles;
2. There is significant demand for linear video content on mobiles;
3. That demand is for linear video content itself, rather than for specific, highly desirable, forms of content;
4. Demand for linear video content on mobiles is consistent and sustained, and will be so for at least the time period of the proposed spectrum allocation;
5. A commercial MTV service is commercially viable, whether FTA or subscription based;
6. Operators, whether broadcast or mobile are willing to invest in acquiring the relevant spectrum and in necessary broadcast hardware;
7. Operators are able to secure access to content necessary to drive sufficient consumer demand to make the service sustainable;
8. Consumers are willing to invest in MTV-enabled smartphones in sufficient numbers to create a viable base for service provision;
9. Operators are able to monetise access to MTV services via subscriptions or advertising, and to generate sufficient revenue to make the service sustainable;

Prima facie it is difficult to envision changes to the current state of Thailand's mobile sector which would result in all of the above conditions existing. Crucially, the absence of any of these conditions is likely to be fatal to a successful long-term MTV deployment. It should be noted that most of the listed conditions also apply for the decision on the introduction of LTE eMBMS in Thailand. Although eMBMS is flexible in its allocation of capacity between unicast and broadcast, it should be checked if capacity will be fully utilized with unicast traffic (as eMBMS will require carrier aggregation, see Section 2.2.3, and that comes in capacity increments) and future LTE volume assessments do include video (including linear services).

On the basis of the above presented list of conditions, it is also argued here that only an in-band spectrum reservation is justified at this moment, given the current market situation in Thailand.

6.3 Long term future considerations

In its assessment to reserve MTV spectrum in the longer term, the NBTC should consider technology developments. The commercial viability of a MTV service will be dependent on securing a spectrum allocation of sufficiently long duration. Given the length of time that is likely to elapse between the submission of this report and a full commercial launch of an MTV service, any assignment would have to run until at least into the 2020s. In this timeframe the availability of competitor technologies beyond currently available LTE-eMBMS becomes relevant to determining whether a reservation of spectrum for MTV is desirable.

LTE-eMBMS has now been commercially deployed by 2 operators globally and is capable of streaming linear HD video content to smartphones under most operating conditions. It would be difficult to argue that there will be widespread take up of a MTV system which offers only SD when competing smartphones and networks are able to deliver HD video. This is specifically the case for T-DMB which is competing with 4G in South Korea (see Section 3.1)[91]. High picture quality is needed in the case where demand is driven by premium content, as is likely.

In addition, based on historic trends it can be expected that 5G, or whatever technology is successor to 4G/IMT-Advanced, will begin to be commercialised in the early 2020s. Even assuming Thailand is not an early adopter, by the time an MTV allocation is between 5 and 10 years old it will be facing competition from LTE-A (including future improvements and developments), and potentially from 5G services.

Consequently MTV systems need to be further developed, like the LTE systems, to remain competitive from a technological point of view. Here handset volumes and large market sizes are critical, as they will provide incentives to further technology investments. As observed in Section 2.1 only in two countries MTV services are commercially offered (i.e. Japan and South Korea). Whereas LTE-A (the system predecessor needed for launching eMBMS) is already deployed in 15 countries across the world. This situation argues the case that the development of LTE based systems will go faster.

Hence the possibilities for MTV systems in the longer term will be limited and possibly only to applications such as the tower overlay (as presented in Section 3.4.2) and in-band systems for other use cases (like on the basis of the DVB-T2 system, see Section 3.3.1).

[91] It should be noted that ISDB-T_{mm} and DVB-T2 Lite are capable of delivering high quality video efficiently.

7. Spectrum Management and Regulations

This Chapter addressed key considerations on spectrum management and regulations if the NBTC would opt for either a specific MTV spectrum carve out (i.e. reserving a multiplex) or allowing DTTB or digital radio in-band use for MTV services, as described in the previous Chapter 6.

7.1 Spectrum management considerations

Spectrum management considerations are different for a specific spectrum allocation for MTV (i.e. spectrum carve out) or an in-band allocation for MTV services (i.e. allowing MTV services in a broadcasting multiplex).

7.1.1 Spectrum carve out for MTV

As outlined in Chapter 6 it is unlikely that a reservation of specific spectrum (i.e. a specific multiplex) for MTV is necessary, or indeed desirable. From a spectrum management perspective such a reservation would add a layer of complexity to Thailand's spectrum allocation processes. There would need to be a process for determining what spectrum to reserve, which would depend on the specific MTV technology standard chosen. A further issue is that any candidate band chosen can also be a candidate band for wireless broadband deployments such as 3G, LTE or even LTE-A. T-DMB seems to be exempt from this consideration as this system typically operates in the VHF Band. However this system seems to be at the end of its technological life.

Given that it is unlikely for an MTV service in Thailand to be commercially viable, the issue of MTV competing with 3G/LTE/LTE-A (4G) for spectrum is challenging. Depending on the market demand for LTE based services and available spectrum (i.e. spectrum not currently allocated for broadcasting services in the Thai national spectrum allocation table), these LTE based technologies may have to be prioritised over MTV by the NBTC. For this reason, and because the appropriate frequency would be determined by the specific MTV system chosen, no specific bandwidths are recommended as candidates for an MTV multiplex allocation in Thailand.

7.1.2 In-band reservation for MTV

For an in-band reservation the situation is different. In the Thai national spectrum allocation table the following bands are allocated for broadcasting services, relevant for the selected MTV systems (see Section 2.1.2):

1. 174 – 230 MHz (VHF Band III);
2. 510 – 790 MHz (UHF Band IV and V, channels 26 to 60).

It should be noted that the allocation in the VHF Band IV/V deviates from the Region 3 Band allocation in the ITU Radio Regulations, in the sense that Thailand allocated channels 21 to 25 (470 MHz to 510 MHz) to Mobile whereas the television band allocation for Region 3 includes these channels. Also the 700 MHz band (channels 49 and up) are allocated to broadcasting on a primary bases only in Thailand, whereas it is commonly expected that in the WRC'15 this band will be allocated on a co-primary basis to allow both for Broadcasting and Mobile (i.e. IMT). It is not expected that lower part (channels 21 to 25) will change its allocation in the Radio Regulations after the WRC'15 is concluded.

The frequency planning work for both DTTB and Digital Radio Broadcasting (DSB) have been completed for Thailand and provided insight into the frequencies needed for national and local DTTB/DSB services[92]. The following can be concluded from these reports:

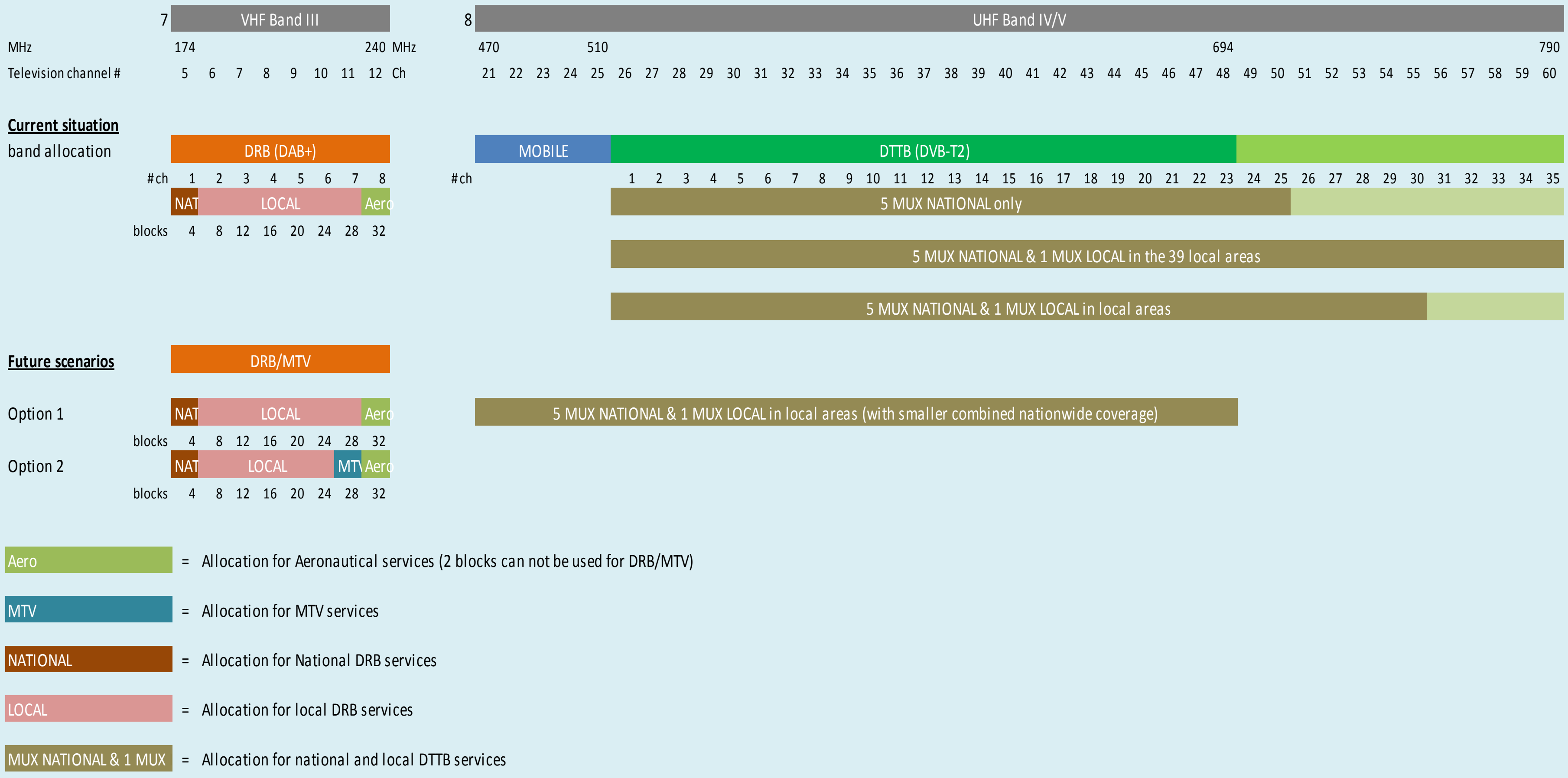
1. For the four national DSB multiplexes one channel (=4 blocks or multiplexes) is needed (with an additional channel for in the south as to comply to the coordination agreement with Malaysia[93]);
2. For the four local DSB multiplexes, six channels (=24 blocks) are needed (i.e. six frequencies per layer times four multiplexes in each local area[94]);
3. For five national DTTB multiplexes 25 channels are needed;
4. For five national and one local DTTB multiplex, following the borders of the 39 defined local areas, 35 channels are needed;
5. For five national and one local DTTB multiplex, not following the borders exactly but its total national coverage being equal to the national multiplexes, 30 channels are needed.

In Figure 52 the above spectrum allocations are illustrated (the top half of the figure, 'current situation')

[92] See ITU report "Detailed planning of additional DTTB sites after ASO", dated February 2015 and LS report "Radio Frequency Plan Project", dated May 2015.

[93] This is channel 7, which is also used in the north for the local layers, in other words far away from the south where channel 7 is used in the national layer for complying with the coordination agreement with Malaysia. Effectively one can say that the national layer shares one frequency (channel 7) with the local layer.

[94] Which are equally defined as the local areas for DTTB.



Source: ITU

FIGURE 52: DTTB AND DSB SPECTRUM ALLOCATIONS

Figure 52 shows that with the current available spectrum all DTTB requirements can be fitted in the UHF Band. However this requires utilizing frequencies in the 700 MHz band. For the VHF Band, all DSB requirements can be fitted in. Also considering the Aeronautical allocation in Channel 12 (which is not included in the Thai frequency allocation table), leaving 2 blocks unusable for DSB. Please note that Figure 52 shows the situation that all four blocks in channel 12 are not utilised[95] (i.e. there is some slack left beyond the DSB requirements).

For future scenarios Figure 52 shows that an allocation of the 700 MHz band (channels 49 and above) to IMT and the allocation of channels 21 to 25 to DTTB, five national and one local multiplex can be fitted into the available spectrum. However without the requirement to follow the borders of the local areas as best as possible and with a somewhat lower combined national coverage. All the DSB requirements, being four national and four local multiplexes, can be facilitated in VHF Band in the future. Especially as no alternative allocation in this part of the band are internationally considered or proposed.

As the DTTB requirements can just be accommodated in the UHF Band, there is no room left for MTV allocations without claiming spectrum in the 700 MHz band. As indicated in Section 7.1.1 this is not recommended. Consequently, also from a spectrum availability perspective, only and in-band reservation for MTV services can be considered in the UHF Band. Unless significant DTTB capacity will be sacrificed which is unlikely as in the future more (U)HD services will have to be facilitated.

For the VHF Band two options exist:

1. Like with the UHF Band in-band reservations are possible. Please note that as indicated in Section 2.1.3 all selected MTV systems could technically operate in the VHF Band. However in contrast with DTTB, such an in-band reservation would claim a considerable amount of the DSB capacity;
2. Depending on the final requirements for local DSB services[96] and utilizing two blocks in channel 12, a spectrum carve out may be possible. Keeping this option open is fairly easy as internationally no alternative allocations are proposed or considered. In addition it could create an extra option for DSB services carried on DVB-T2 Lite, as proposed by some industry parties (see also Section 3.3.2).

7.1.3 Spectrum reservation and system choice

In this Section the recommendations on spectrum carve-out and in-band reservations are combined with the three selected MTV systems for Thailand (see Section 2.1.2). Table 7 shows the possible combinations.

	Spectrum carve-out	In-band reservation

[95] The frequency plan as produced by LS Telecom also avoids all blocks in channel 12, see footnote 92 for the report reference.

[96] As in terms of spectrum capacity these local DRB services claim far more than the 20% capacity claim that can be justified on the basis of the Broadcasting Act.

	Spectrum carve-out		In-band reservation	
UHF Band IV/V	**NO**	-	**YES**	DVB-T2-L only
VHF Band III	**YES** small	ISDB-T_{mm} DVB-T2-L	**YES**	T-DMB only

TABLE 7: OPTIONS FOR SPECTRUM MANAGEMENT AND SYSTEM COMBINATIONS

When considering the options as presented in Table 7, the following should be noted:

1. Introducing ISDB-T_{mm} in a carve-out part of the VHF Band would imply the introduction of a new transmission standard in the Thai market (see also Section 3.2.1);
2. The introduction of DVB-T2 Lite in the VHF Band would also bring an extra option to introduce DSB on the basis of this standard (see also Footnote 66);
3. The in-band options are dependent on the current situation of having DAB+ for DSB and DVB-T2 for DTTB. Changing or introducing other DSB/DTTB systems may lead to other in-band options.

7.2 Regulatory considerations

In this Section some regulatory considerations are addressed that may shed a different light on the introduction of MTV (or LTE eMBMS) services.

7.2.1 Universal Service

It may be argued that linear television services delivered on handheld devices (either MTV or LTE based) could be considered a Universal Service, warranting a spectrum carve out.

However MTV or LTE eMBMS based broadcasting of video content should not fall within Thailand's Universal Service regime. Whether they are standalone services or add-ons (in-band) to existing services would depend on the exact form of any deployment and on the operator providing the service. Regardless of the form or the operator it would not be appropriate for MTV or LTE based video services to be subject to Universal Service requirements.

Fundamentally, access to video content on a mobile is not a basic service to which everyone should be entitled. MTV and LTE based services represent a more efficient method of delivering live video content to those who already have access to it by other means (i.e. DTTB, satellite or cable based delivery systems). These alternatives are available to the Thai people (see Section 4.1). It would be incongruous if access to MTV or LTE-eMBMS were subject to Universal Service requirement where ownership of a smartphone was not. Additionally it could not be argued that widespread access to MTV or LTE-eMBMS would have such benefits for Thai society as a whole that Universal Service should be imposed. This is in contrast to services such as basic telephony and, potentially, broadband, whose benefits to inter alia commerce, social cohesion and emergency response are so overwhelming that Universal Service of them makes sense.

7.2.2 Broadcasting mobile services along existing TV services

Two primary issues arise where an LTE/MTV operator would like to broadcast video content which has been or will be broadcast on another platform, such as DTTB. Firstly, the LTE/MTV operator would need to secure rights for use of the content, from the copyright holder and potentially from any party with an exclusive license over the content in Thailand. Secondly, if the operator wanted to broadcast using an LTE/MTV network it would require a television Service license from the NBTC, and depending on the NBTC's interpretation of licensing requirements, may need one in order to provide communication services in the case of LTE services.

It is unlikely that the LTE/MTV operator's broadcast and a DTTB broadcast would be in the same market. In essence it is very unlikely that they would be substitutes. The test for substitution is whether consumers would swap to the other product in response to a small but significant and non-transitory increase in the price of the original product. Using this test it is extremely unlikely that an LTE/MTV broadcast would be a substitute for a DTTB broadcast.

In order to be a substitute Thai consumers would need to switch their preference for DTTB to LTE/MTV in response to a small but sustained increase in the price of DDTB services. This raises a fundamental problem in that smartphone penetration in Thailand is small in comparison to television penetration. Put simply, for the services to be substitutes Thai consumers would need to be willing to purchase a smartphone in response to a small increase in the cost of DTTB services.

7.2.3 Assignment of MTV licenses to cross industry consortia

In Japan the rights to operate MTV services (NOTTV) was assigned to a consortia of market players from both the broadcasting and telecommunications industries (see Section 3.2). To a large extend this consortia comprises a vertically integrated supply chain from content to handheld.

The relevant license for a NOTTV style service in Thailand would be a television service license. The NOTTV service operates standalone channels using standalone spectrum, it is in effect a television broadcasting service which aims its content at smartphone users. The complication for the purposes of licensing in Thailand is the requirement that consumers possess a smartphone to receive and view the broadcast. Absent a significant market for the outright purchase of such phones a joint venture or consortium with a mobile service provider would be necessary to ensure a viable pool of potential customers.

Realistically the implementation of such a service would require a collaboration between a broadcast license-holder and a mobile operator. This would lead to the conclusions that the assignment procedure for these NOTTV style license, had to include requirements for collaboration between industry parties (needed for successfully delivering such converged services). However this raises issues of whether all involved parties would need to hold both mobile and broadcast licenses, or if not, which licenses each entity would need.

It should be noted that NOTTV itself is operated by NTT/DoCoMo, a vertically integrated operator which already held all the relevant licenses. NOTTV only works on devices supplied by NTT/DoCoMo, however its subscriber base is sufficiently large to make NOTTV a commercially viable service. It is at best questionable whether any operator or consortium in Thailand would be in a position equivalent to NTT/DoCoMo in Japan.

Hence there are two important arguments provided in this report not to assign a NOTTV style license in the UHF Band. First, a spectrum carve out for a NOTTV license would require marked and other conditions to be met (see the list of conditions in Section 6.2). A (near) future scenario in which these conditions are met are assessed to be very unlikely. Secondly, from a spectrum availability point of view, a carve-out cannot be carried out in the UHF Band without sacrificing DTTB spectrum.

It should be noted that in the VHF band two low cost options would exist but would need clarification on the final requirements for local DSB services.

7.2.4 Expansion of licensed services.

For allowing MTV services to be broadcasted as in-band services, it should be assessed whether the current Thai regulatory framework would allow for such a service expansion. And if so, if any changes are needed.

In general allowing licensees to provide services they are authorised to provide via different technologies would be consistent with regulatory best practices technology neutral licensing. For example allowing DTTB licensees to provide DVB-T2 Lite services. In particular, as DVB-T2 Lite is specific profile of the already existing digital broadcast (DVB-T2) standard there would be little principled reason to prevent existing DTTB licensees from implementing it.

However, two potential issues arise. First, it is not clear that Thailand's broadcast licensing regime is technology neutral and as such would allow such mixing or updating of the technologies used to broadcast. Where a license is tied to a specific technology such an implementation would amount to a breach of the license conditions with the ultimate potential for revocation of the broadcasting license itself. Second, in the case of allowing DAB+ licensees to provide Smart T-DMB services it would be almost entirely distinct services provided. It is questionable whether a license for broadcast of audio services would support broadcast of video content, even if technology neutral licensing were in place.

At a basic level best practices would be to allow for a licensee who is authorised to broadcast video content to do so using whatever technology they deemed best for doing so (subject to interference and QoS limitations). This would allow for DTTB providers to add DVB-T2 Lite services, but would not cover DAB+ licensees adding Smart T-DMB services. However, given Thailand's licensing regime was not implemented based on the principle of technology neutrality such an approach is unlikely to be in line with Thai law. As a result adding such services would likely require securing a license specifically authorising them.

8. Conclusions and recommendations

In this Chapter the main conclusions are listed, followed by recommendations for the NBTC to consider in further developing its policy and regulations on MTV services.

8.1 Conclusions

This feasibility study on mobile television services was carried out with careful consideration of the developments and convergence trends observed globally. As many multimedia services are offered nowadays, the mobile television services had to be further categorized as to understand difference better:

1. Mobile Television (MTV) services are defined as linear television services (and possibly data) delivered over a managed *broadcast* network whereby the picture quality is actively managed. It may have integrated interactive services, including VOD services, delivered over a switched (IP based) mobile network. The delivery of the MTV services is intended for reception on vehicle build-in and handheld devices in all user environments;
2. Mobile video services are defined as linear television (and possibly data), VOD and interactive services delivered solely over a managed (IP based) mobile network whereby picture quality may be managed. The delivery of the mobile video services is intended for reception on handheld devices in all user environments.

Recommendation ITU-R BT.1833-3 (02/2014) covers eight standards for MTV services delivered by digital broadcast networks (MTV) of which two are satellite systems and six are based on terrestrial networks. On the basis of a technical review of these six transmission standards and considering the broadcasting systems selected or deployed in Thailand, three systems were identified as potential candidates for a transmission standard for MTV services in Thailand:

1. (A)T-DMB;
2. DVB-T2 Lite;
3. ISDB-T_{mm}.

Mobile video services are typically delivered by a system called Long Term Evolution (LTE). LTE is an advanced telecommunications platform which has been designed as an all-purpose base platform. This base platform can be further developed for the long term, hence the name. In a further effort to increase the systems efficiency LTE-Advanced (LTE-A) was developed. This platform provided the basis for delivery of mobile video services. In order to provide broadcasting functionality the Multimedia Broadcast/Multicast Service (MBMS and the enhanced version -eMBMS) were developed as part of the LTE system's evolution.

In their implementation and functionality MTV and LTE eMBMS systems fundamentally differ. As LTE eMBMS systems can switch between unicast and broadcast mode in a selected number of network cells the LTE system is very flexible. This in contrast to MTV systems which typically broadcast their services in large coverage areas on a 24/7 basis. However in-band MTV system implementations have the flexibility to switch capacity between the base (DTTB/DSB) and mobile services.

The LTE flexible system functionality is typically designed for broadcasting television services around events (like football matches or music concerts), which take place during a limited period and in a specified/limited area of the network. Traditional television services are typically broadcasted 24/7 (see Section 1.2) and therefore the LTE eMBMS functionality is not comparable in this aspect to MTV systems.

However which functionality would be required is demand driven. The demand for different type of services, more specifically Video on Demand (VOD) and live/linear television (including 24/7) services should be addressed.

There is no hard global or local data available on how much percent of total mobile video traffic is live video (versus VOD). From interviews with Thai mobile operators it was understood that although they offer live video/television services the fast majority of video traffic was consumed for catch-up television. For missed episodes of popular mainstream television soaps, mobile video users stream the missed episode to their handheld (i.e. VOD). Traffic volumes for mobile video were still limited due to the relatively low penetration rate of smartphones and the data-packages offered. Watching video is relative expensive as it eats up data quickly.

In a further analysis of demand it was concluded that live/linear content on mobiles is likely to experience significant peaks and troughs, with significant demand when 'must-see' content is available and far less demand at other times. Critically, the existence of demand for linear content on mobiles at peak times does not mean that there is sufficient demand for live content in general to warrant an MTV spectrum reservation (spectrum carve out). Unless this spectrum reservation comes with a very low spectrum claim (like with in-band systems). In short, if there is not sufficient 24/7 demand for linear video on mobiles, the existence of demand at peak times may not make an MTV service viable (and ultimately market parties should also assess such viability).

Where demand for linear content spikes and then dissipates the capability of LTE-eMBMS to dynamically assign spectrum to either broadcast or unicast mode is likely to be more effective at meeting consumer demand overall. However mass market delivery of live events (i.e. large proportions of the populations and nationwide service availability) may still require broadcast systems.

No single specific scenario could be devised in which a reservation of spectrum (spectrum carve out) for a MTV multiplex would makes sense in Thailand. A series of requirements would need to be met in order for such a reservation to be justified. This is especially the case given that UHF spectrum suitable for MTV is in high demand for LTE deployments and DTTB HD services.

As the current DTTB requirements can just be accommodated in the UHF Band, there is no room left for MTV allocations without claiming spectrum in the 700 MHz band. Only an in-band reservation for MTV services can be considered in the UHF Band. Unless significant DTTB capacity will be sacrificed which is unlikely as in the future more (U)HD services will have to be facilitated.

For the VHF Band two options exist:

1. Like with the UHF Band in-band reservations are possible. However in contrast with DTTB, such an in-band reservation would claim a considerable amount of the DSB capacity;

2. Depending on the final requirements for local DSB services and utilizing two blocks in channel 12, a spectrum carve out may be possible. Keeping this option open is fairly easy as internationally no alternative allocations are proposed or considered. In addition it could create an extra option for DSB services carried on DVB-T2 Lite, as proposed by some industry parties.

It was concluded that mobile video services could not be classified as a Universal service as alternative forms of receiving television services are available to the public in Thailand. Some regulatory measures may be necessary depending on the type of spectrum reservation (i.e. in-band or spectrum carve out), including the possibility for an in-band reservation for MTV services in a DSB multiplex. Also technology neutrality may have to be addressed in the current licensing framework.

8.2 Recommendations

While it is technically viable for an MTV service to be deployed in Thailand, it is currently doubtful that the conditions necessary for a successful commercialisation of such a service exist. Given current patterns of demand for video content, smartphone penetration, and impending technological developments, it is unlikely that a business case for deploying and operating an MTV network could successfully be made out. Also in the UHF band these MTV services will compete for the same spectrum as IMT/LTE services, which are assessed to be more valuable for the Thai society (depending on the forecasted demand for unicast traffic and available spectrum for mobile services).

Hence it is recommended to proceed carefully and not to carve out any specific spectrum in the UHF Band for MTV services in Thailand. In the VHF Band the NBTC may consider a relative small carve out, depending on the final requirements for local DSB services.

Furthermore the NBTC is recommended to consider providing in-band reservations on DTTB and DSB multiplexes. Such in-band options come with low costs in terms of spectrum claim (as in-band systems can switch between the base and mobile service) and network costs (as in-band functionality is standard and inherent functionality of MTV systems). In addition, providing this option to current licensees may help to further improve their business case for the base services (either DSB or DTTB services).

Combining the recommendations for spectrum management with the selected MTV systems, results in several combinations as presented in Table 8.

	Spectrum carve-out		In-band reservation	
UHF Band IV/V	**NO**	-	**YES**	DVB-T2-L only
VHF Band III	**YES** small	ISDB-T_{mm} DVB-T2-L	**YES**	T-DMB only

TABLE 8: OPTIONS FOR SPECTRUM MANAGEMENT AND SYSTEM COMBINATIONS

With the NBTC agreeing not to carve out any UHF spectrum and selecting one or more of the other provided options for MTV services, a further policy strategy and regulations can be developed for facilitating these options.

Glossary of Abbreviations

3GPP	Third Generation Partnership Project
AAC	Advanced Audio Coding
ARIB	Association of Radio Industries and Businesses
ASO	Analogue Switch-Off
AT-DMB	Advanced Terrestrial – Digital Multimedia Broadcasting
ATSC	Advanced Television Systems Committee
ATSC-M/H	Advanced Television Systems Committee – Mobile/Handheld
AVC	Advanced Video Coding
BMP	Broadcasting Master Plan (of NBTC)
BM-SC	Broadcast/Multicast Service Centre
BTS	Base Transceiver Station
CA	Carrier Aggregation
CAS	Conditional Access System
CDMA	Code Division Multiple Access
CMMB	China Mobile Multimedia Broadcasting
CoMP	Coordinated Multi Point operation
DAB	Digital Audio Broadcasting
DeNB	Donor evolve Node B
DFT	Discrete Fourier Transform
DL	Down Link
DQSPK	Differential Quadrature Phase Shift Keying
DRM	Digital Rights Management
DSB	Digital Sound Broadcasting
DTTB	Digital Terrestrial Television Broadcasting
DVB-H	Digital Video Broadcasting – Handheld
DVB-T2	Digital Video Broadcasting – Terrestrial 2nd generation
EBU	European Broadcasting Union
EBU	European Broadcasting Union
eMBMS	evolved Multimedia Broadcast/Multicast Service
eNB	Evolved Node B
eNodeB	Evolved Node B
EPC	Evolved Packet Core
EPS	The Evolved Packet System
E-RAB	E-UTRAN Radio Access Bearer
ETRI	(Korean) Electronics and Telecommunications Research Institute
E-UTRAN	Evolved UTRAN
EWS	Emergency Warning System

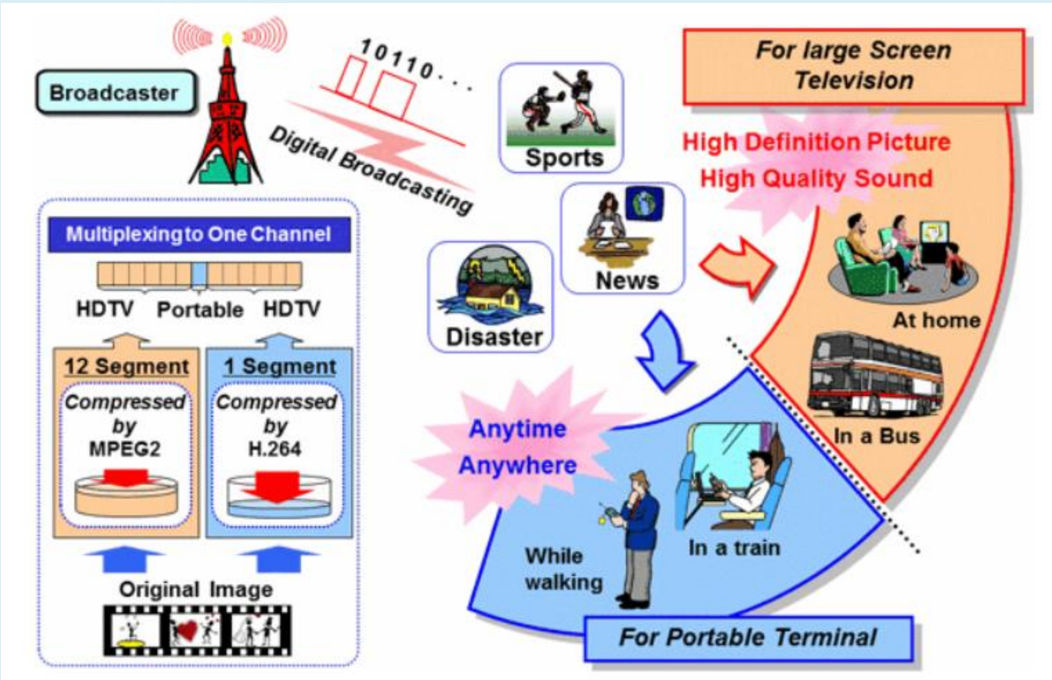
FDD	Frequency Division Duplex
FTA	Free To Air
GSM	Global System for Mobile communication
HeNB	Home evolve Node B
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSS	Home Subscriber Server
HSUPA	High Speed Uplink Packet Access
IMS	IP Multimedia Core Network Subsystem
IMT	International Mobile Telecommunications
IP	Internet Protocols
ISDB-T	Integrated Services Digital Broadcasting – Terrestrial
ISDB-T_{mm}	Integrated Services Digital Broadcasting – Terrestrial Multimedia
ITU	International Telecommunication Union
KBS	Korean Broadcasting System (= National Korean Public Broadcaster)
LTE	Long Term Evolution
LTE-A	LTE-Advanced
MAC	Medium Access Control
MBMS	Multimedia Broadcast/Multicast Service
MBSFN	Multicast-Broadcast Single-Frequency Network
MCCH	Multicast Control Channel
MCE	Multi-call/multicast Coordination Entity
MCH	Multicast Channel
MCS	Modulation Coding Scheme
MFN	Multi Frequency Network
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MPEG	Moving Picture Experts Group
MSC	Main Service Channel
MTC	Multi Cell Transmission
MTCH	Multicast Traffic Channel
MTV	Mobile Television (based on a digital broadcasting network)
MUX	Multiplex
NAS	Non-Access Stratum
NodeB	is a term used in UMTS equivalent to the BTS (base transceiver station)
OB	Outside Broadcasting
OFDM	Orthogonal Frequency-Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PAD	Program Associated Data
PAPR	Peak-to-Average Power Ratio

PDN	Packet Data Network
PMCH	Physical Multicast Channel
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RN	Relay Nodes
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator
RTT	Round Trip Time
SAE	System Architecture Evolution
SC-FDMA	Single Carrier - Frequency Division Multiple Access
SCTP	Stream Control Transmission Protocol
SDK	Software Development Kit
SFN	Single Frequency Network
SIBType2	System Information Block Type2
SMS	Subscriber Management System
SNR	Signal to Noise Ratio
SoC	Systems on a Chip
SU-MIMO	Single User MIMO
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
T-DMB	Terrestrial – Digital Multimedia Broadcasting
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
T-MMB	Terrestrial – Mobile Multimedia Broadcasting
TPEG	Transport Protocol Experts Group (i.e. for traffic information)
UE	User Equipment
UHF	Ultra High Frequency
UL	Up Link
UMTS	Universal Mobile Telecommunications System
USD	User Service Discovery
UTRAN	Universal Terrestrial Radio Access Network
VHF	Very High Frequency
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

Annex A: ISDB-T

The OneSeg mobile television service is implemented as part of an ISDB-T multiplex, all services are carried on one RF channel and hence the same transmitter/network architecture. The OneSeg service is carried over one segment of the 13 available segments. The ISDB-T standard is defined in ARIB STD – B31.

Figure 53 shows a system overview of the ISDB-T system and the OneSeg service implementation on one segment of the total multiplex capacity.



Source: ARIB

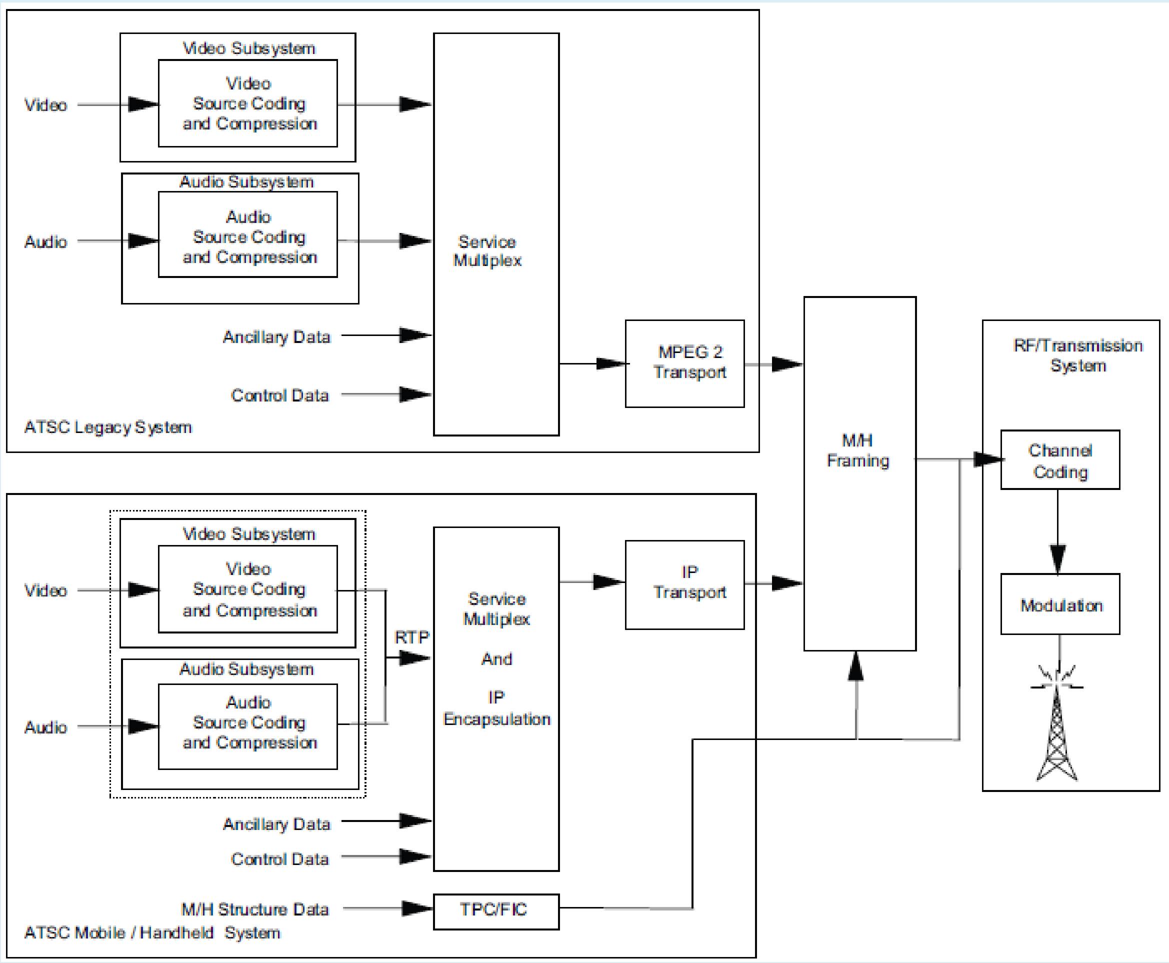
FIGURE 53: ISDB-T SYSTEM OVERVIEW

Annex B: ATSC-M/H

This Annex includes a network architecture overview of the ATSC-M/H system. It is to illustrate that the M/H service is implemented as part of a network architecture delivering the main service (mostly for DTTB services).

For a complete overview of the ATSC-M/H standard, please refer to: ATSC-Mobile DTV Standard, All Parts – ATSC Mobile Digital Television System, Document A/153[97].

Figure 54 shows an ATSC broadcast system with TS Main and M/H services.



Source: ATSC

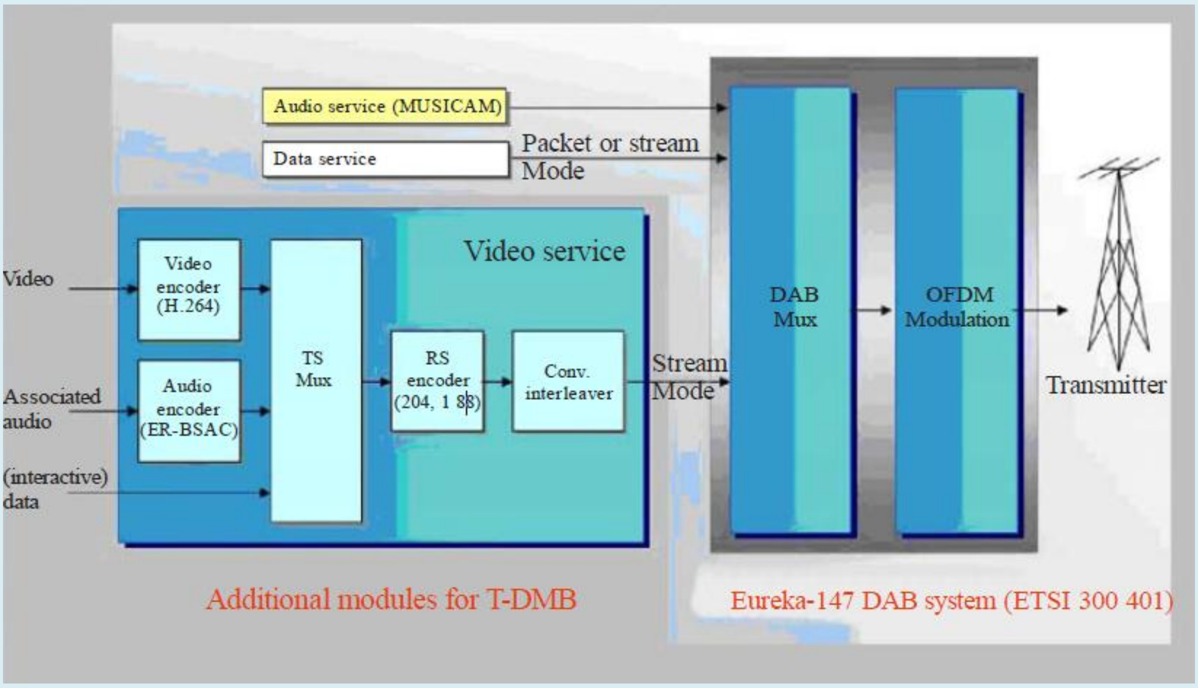
FIGURE 54: ATSC BROADCAST SYSTEM OVERVIEW

[97] The standard can be found on the ATSC website: www.atsc.org

Annex C: T-DMB

T-DMB has been designed exclusively to provide services on mobile and portable platforms. T-DMB is designed to provide video services (please note that this includes audio associated with the video) for users in mobile environment guaranteeing the backward compatibility with DSB System A (i.e. DAB). In the T-DMB stream MPEG-4 AVC (H.264) coding is used for video and AAC (MPEG-4 Part 3 ER-BSAC) coding for audio. Any audio service are delivered by the DAB system in place and can be either MUSICAM for DAB and AAC+ for DAB+ (see also Table 2)[98].

Figure 55 shows the T-DMB and DAB transmission system[99]. As can be seen, the T-DMB modules have been added in front of the original DAB system, without any modifications or changes to the existing DAB transmission infrastructure. Video and audio encoders encode the multimedia/DMB content. Block coding (Reed Solomon encoder, convolutional interleaver) has been included for reliable and stable reception of video/DMB services in a high-speed mobile environment.



Source: ITU

FIGURE 55: ADDITIONAL MODULES FOR T-DMB WITHIN A DAB SYSTEM

98 Please note that DAB+ uses AAC+ (HE-AAC v2) for audio coding too.

99 See ITU-R BT.2049-5, Appendix 2.

Annex D: LTE-A system improvements

Several advanced technologies were introduced to achieve system improvements in LTE's radio access network, including:

1. Carrier Aggregation (CA);
2. Multi-Input Multi-output (MIMO) antenna systems;
3. Support Relay Nodes (RN);
4. Coordinated Multi Point operation (CoMP).

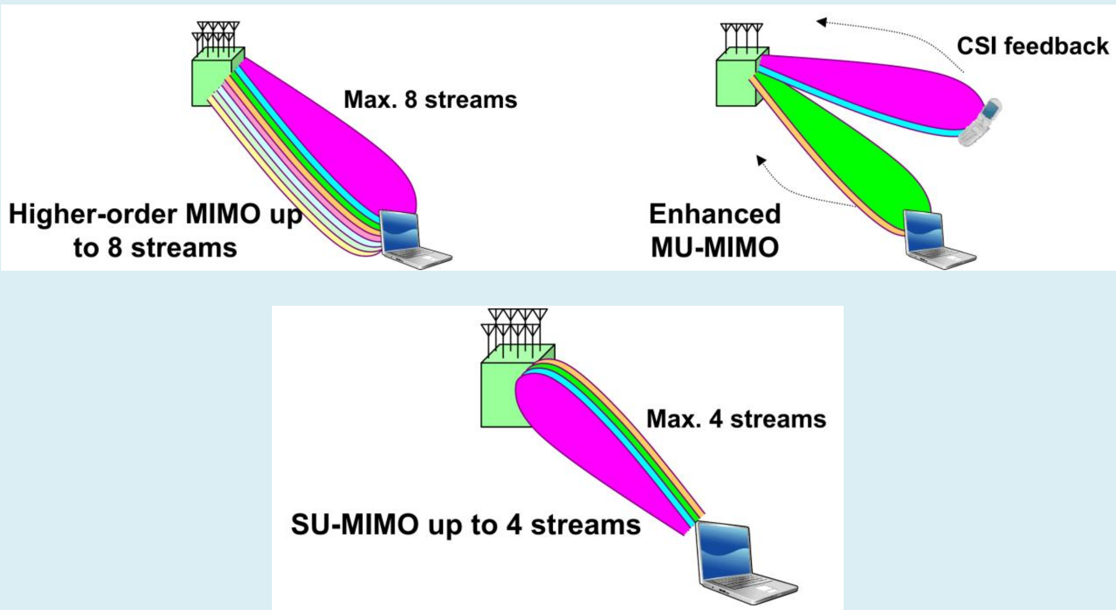
Carrier Aggregation is addressed in Section 2.2.3 of this report. In this Annex the other three technologies are briefly explained.

MIMO

Enhanced use of multi-antenna techniques (MIMO or spatial multiplexing), pre-coding is used to map the modulation symbols onto the different antennas. The aim with pre-coding is to achieve the best possible data reception at the receiver. Its improvements include the following:

1. Extension up to 8-stream transmission
2. Specify additional Reference Signals (RS)
3. Introduction of single user (SU)-MIMO up to 4-stream transmission
4. Signal detection scheme with affinity to DFT-Spread OFDM for SU-MIMO.

The MIMO system principles are illustrated in Figure 56.

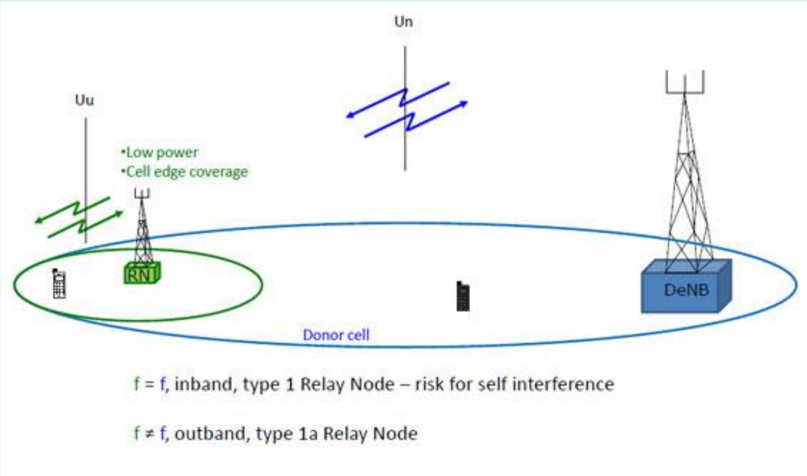


Source: 3GPP

FIGURE 56: MIMO PRINCIPLES

Support Relay Nodes

Relay Nodes are low power base transceiver stations providing enhanced coverage and capacity at cell edges, as well as hot-spot areas. The Relay Node is connected to the Donor eNB (DeNB) via a radio interface, Un, which is a modification of the E-UTRAN air interface Uu. Figure 57 illustrates the principle of RN.

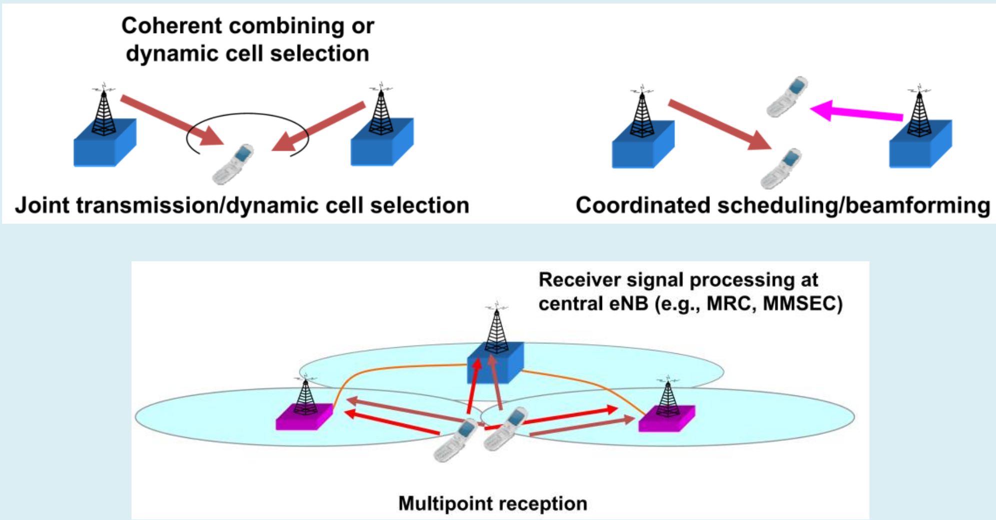


Source: 3GPP

FIGURE 57: RELAY NODE PRINCIPLE

Coordinated Multi Point operation

Coordinated Multi Point operation (CoMP) was introduced in R11 (see Table 3). The CoMP is to improve network performance at cell edges. The coordination can be done for both homogenous networks as well as heterogeneous networks. CoMP transmission in the downlink and reception in uplink are illustrated in Figure 58.



Source: 3GPP

FIGURE 58: COMP PRINCIPLE

Annex E: Detailed coverage maps for in-car reception

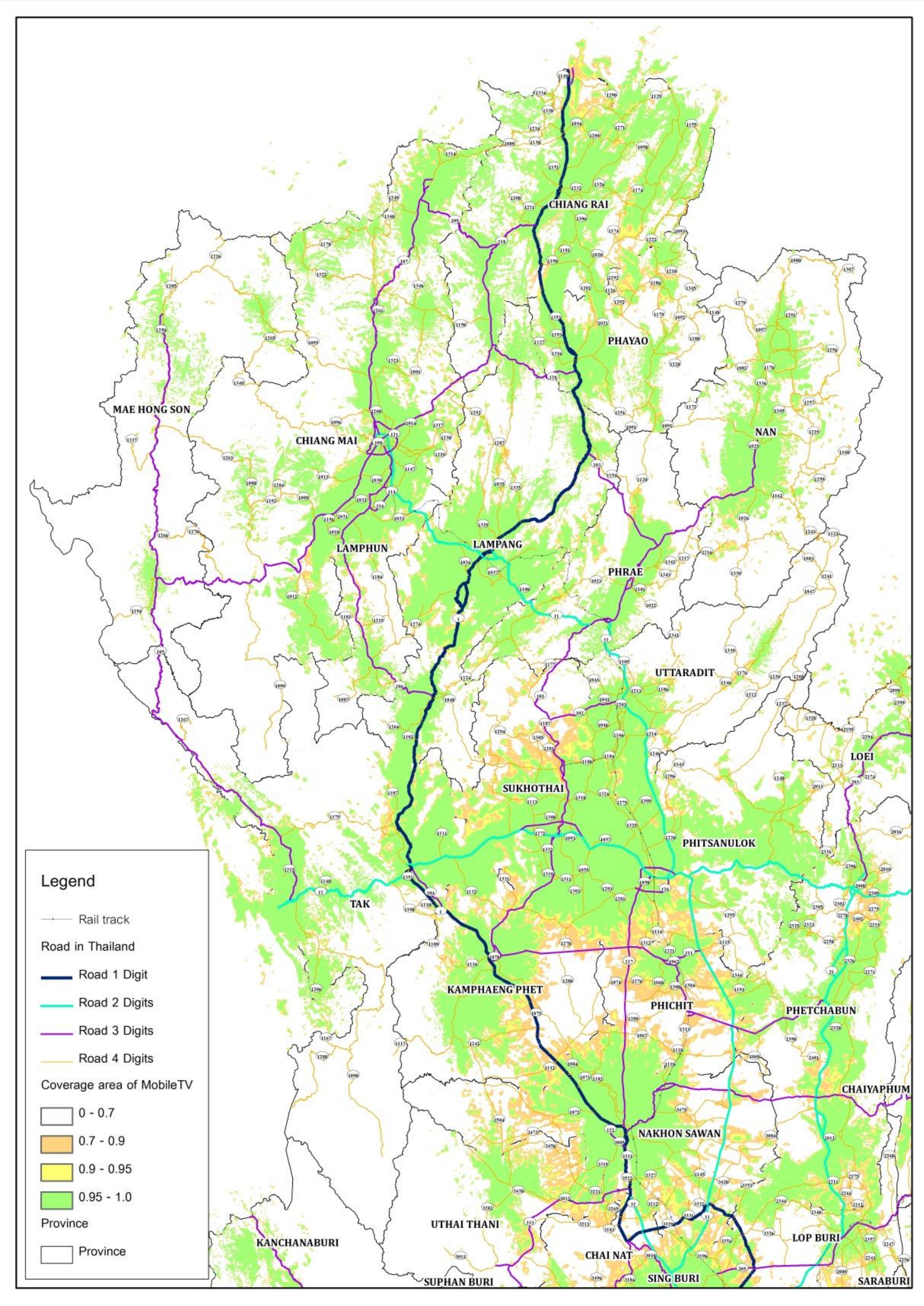
This Annex shows the detailed coverage maps for in-car reception with the current DVB-T2 network in Thailand, fully deployed (i.e. 171 transmitter sites). This network was designed for rooftop reception, however with a robust broadcast mode providing also indoor and mobile reception. For a nationwide in-car or mobile coverage overview see Figure 27 in Section 3.3.1 of this report. The maps are calculated for the noise limited situation.

Table 9 shows the planning parameters used for this initial in-car/mobile coverage prediction:

	Fixed	Mobile
DVB-T2 system variant	FTT size 16k, extended bandwidth, 64QAM, CR 3/5, PP2, guard interval 266 µs	
C/N	Rice	Rayleigh
Receiver height	10m	1.5m
Coverage probability	95%	99% (means 3.8 dB difference)
Antenna gain & cable loss	7dBd	3dBd

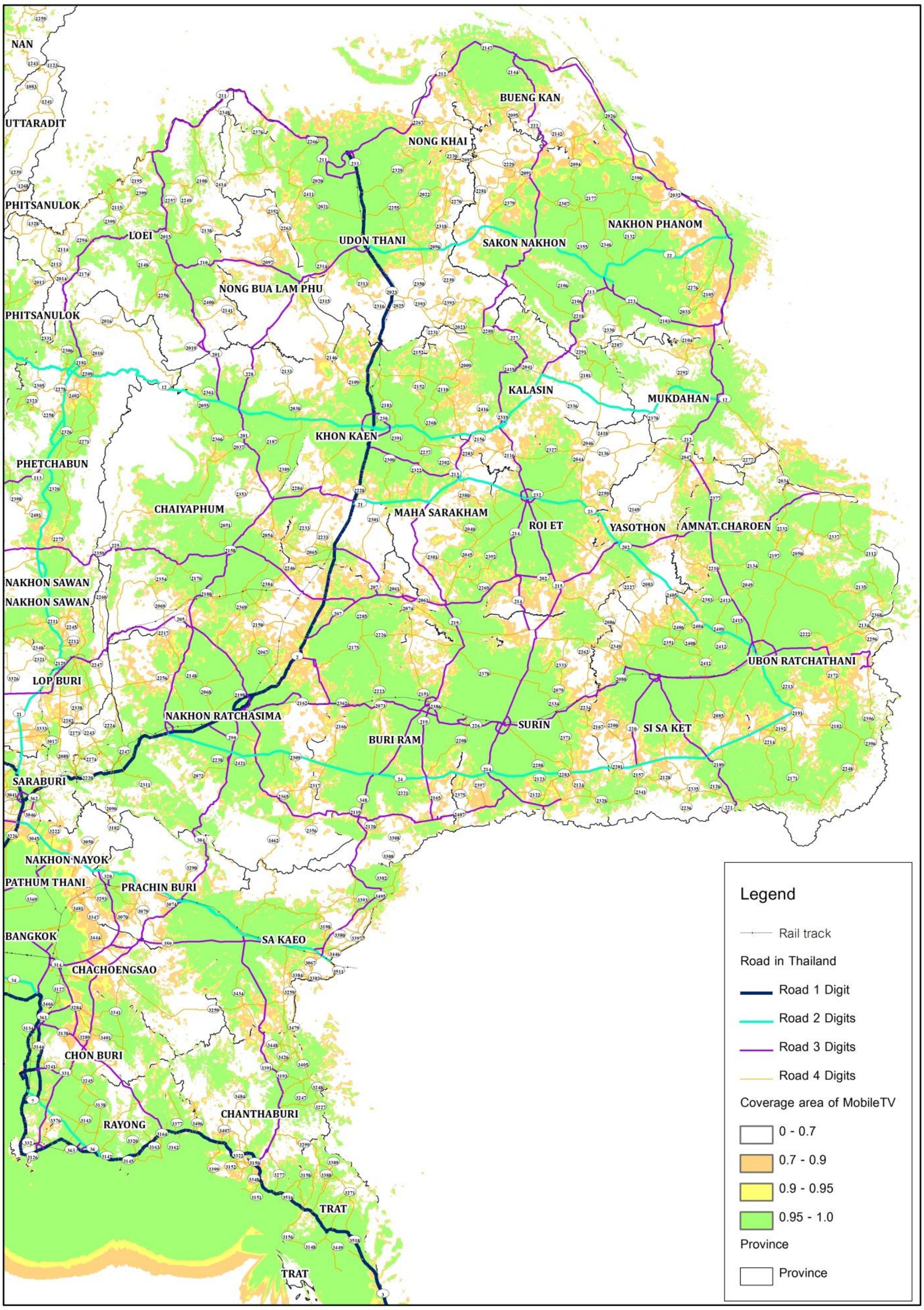
TABLE 9: APPLIED PLANNING PARAMETERS FOR MOBILE RECEPTION

The in Table 9 included set of planning parameters would for channel 47 result in an Emed (medium field strength) for Fixed and Mobile reception of 49.9 and 55.6 dBµV/m respectively.



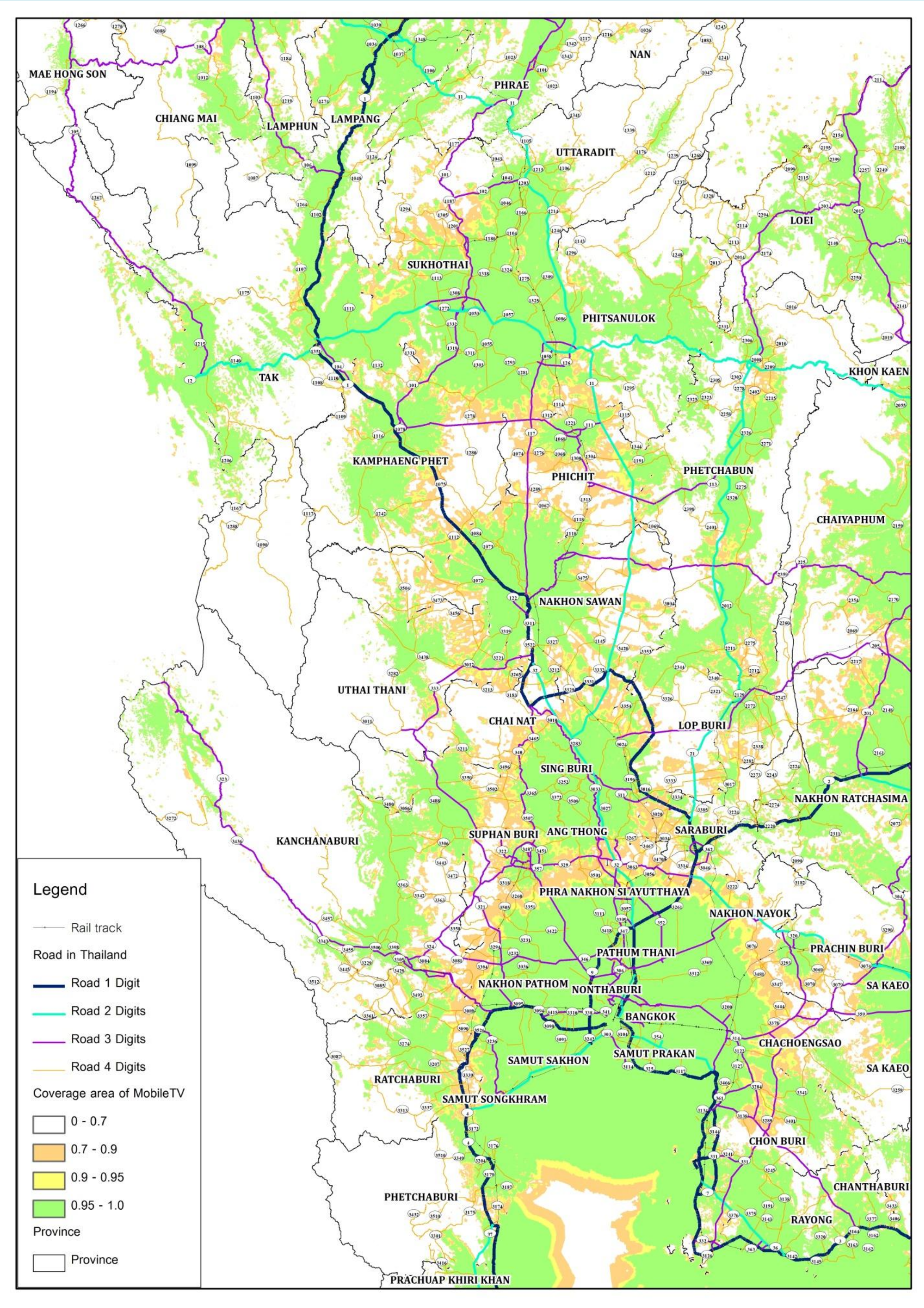
Source: ITU

FIGURE 59: DETAILED COVERAGE MAP 1



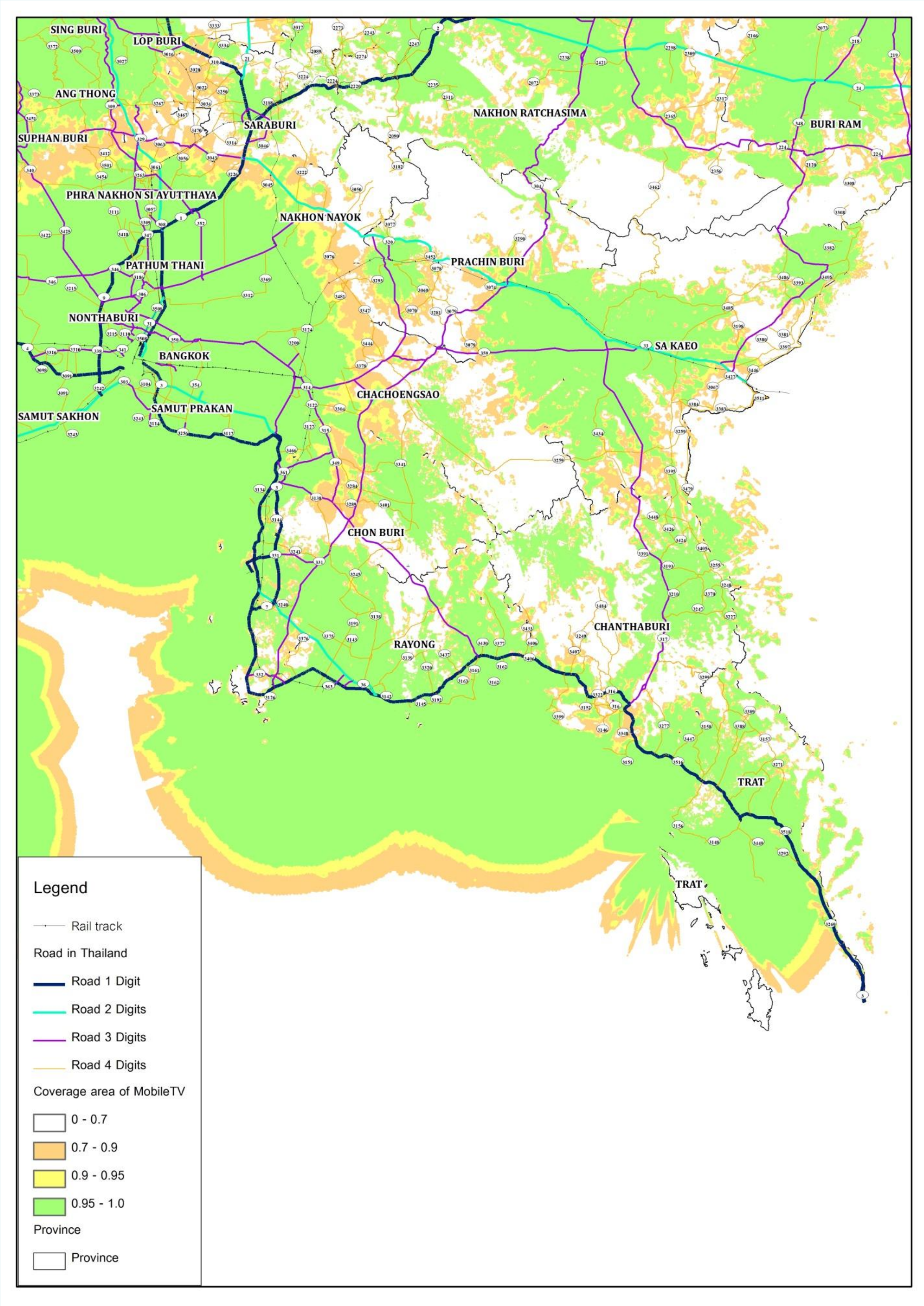
Source: ITU

FIGURE 60: DETAILED COVERAGE MAP 2



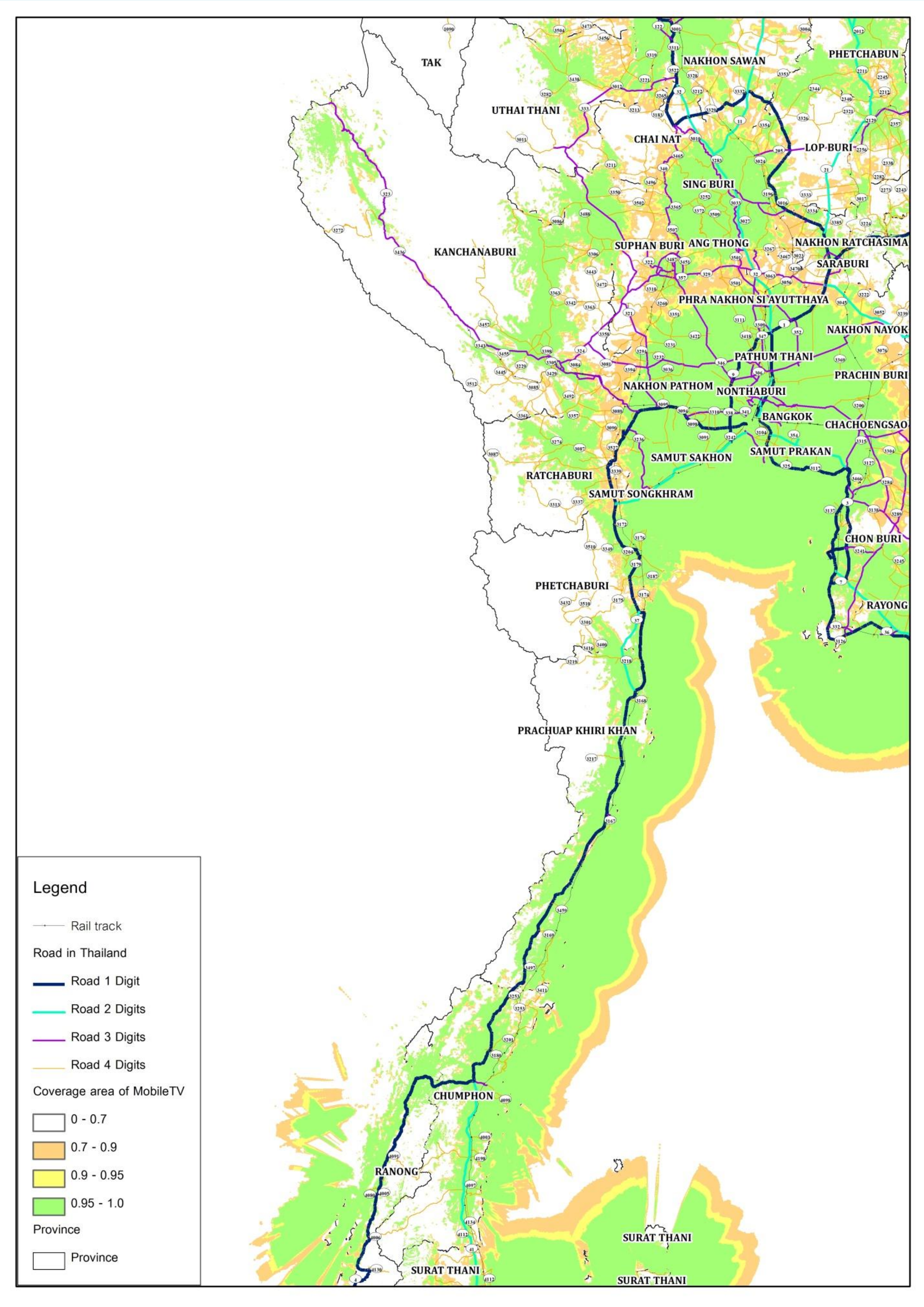
Source: ITU

FIGURE 61: DETAILED COVERAGE MAP 3



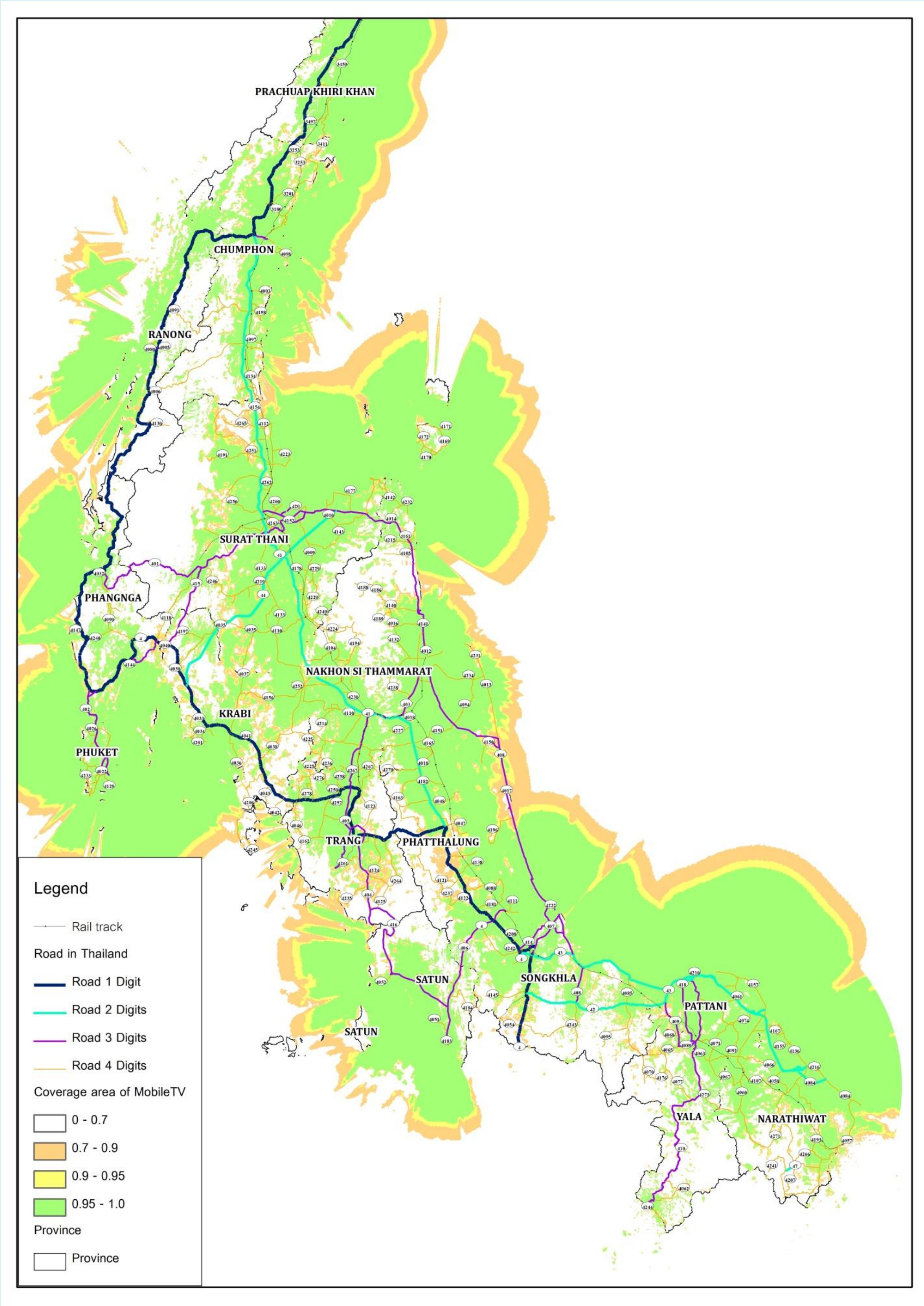
Source: ITU

FIGURE 62: DETAILED COVERAGE MAP 4



Source: ITU

FIGURE 63: DETAILED COVERAGE MAP 5



Source: ITU

FIGURE 64: DETAILED COVERAGE MAP 6


11.45
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