White paper

Technical Overview of **S**ingle **F**requency **N**etwork

Executive Summary:

This paper describes the principles of Single Frequency Network. Scarcity of available spectrum & bandwidth is one of the main issue broadcasters and network operators are facing. The author proposes a comprehensive technical overview of single frequency network: from the Head-End, to the transmission.

Introduction

Considering the fast-growing commercial deployment of new terrestrial and mobile Tv services (DVB-T, DVB-H, DTMB etc...), broadcasters and network operators are facing frequency shortage. Besides, taking into consideration the price of broadcasting licences, operating a network where spectrum/bandwidth is optimized becomes more efficient as regards to the business plan.

Based on COFDM modulation properties, the Digital Video Broadcasting (DVB consortium) introduced a way to optimize spectrum & bandwidth for DVB-T and DVB-H broadcast, namely Single Frequency Network (SFN). SFN topology contrasts with MFN (Multiple Frequency Network) topology, where all the transmitters broadcast over a different frequency.

Within a Single Frequency Network, all the transmitters from one SFN cell will broadcast over the same frequency, enabling spectrum & bandwidth optimization.

The challenge is thus to provide all the transmitters with necessary information in order to broadcast over the same frequency.

The picture below perfectly illustrates the problematic: in MFN, three different broadcast frequencies are in use, with 24 MHz bandwidth occupied. In SFN, only one frequency, with bandwidth optimization: only 8 MHz.

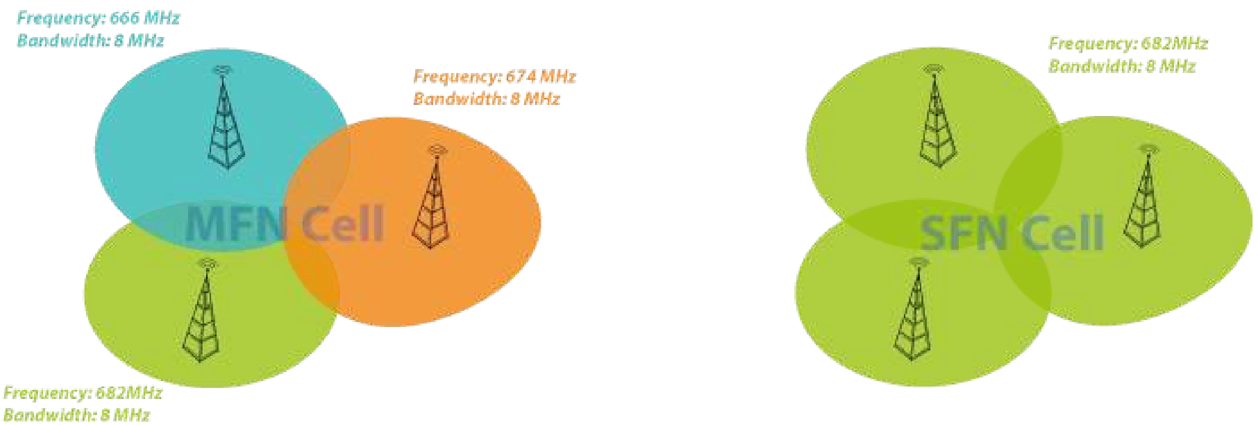


figure 1: Comparison between MFN and SFN topology

Requirements for building-up one SFN Network

In order to set up one SFN network, three conditions have to be fulfilled. DVB-T/H Transmitters belonging to one SFN cell shall radiate:

1. ***over the same frequency***
2. ***at the same time***
3. ***the same OFDM symbols***

The first condition is basically easy to satisfy: all the DVB-T or DVB-H transmitters will be configured once to the required broadcast frequency (at the modulator level).

Conditions 2) and 3) imply to provide transmitters with extra information: synchronization and transmission parameters. This is specifically the task of the Single Frequency Network (SFN) adapter: SFN adapter will add to the TS stream all the information required by the transmitters.

Optional data can be transmitted to address individually transmitters (delay transmission, add frequency offset etc.). Depending on the standard (DVB-T/H, DTMB, DVB-SH ...) optional functions can differ. Athough optional, functions like *tx_cell_id()* are often required by modulators configured in SFN.

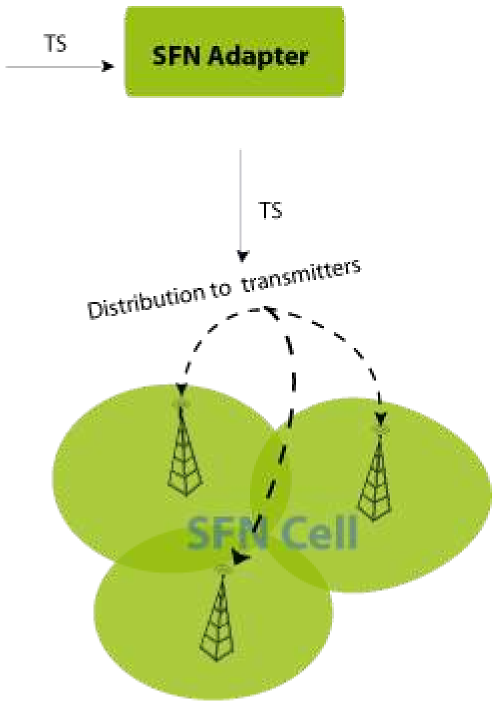


figure 2: A simple SFN network

MIP Packet: Megaframe Initialization Packet

Synchronization and transmission information sent to transmitters are stored into one TS packet called MIP packet (or table). DVB normalized its PID to 0x15. The content of this table can be viewed this way:

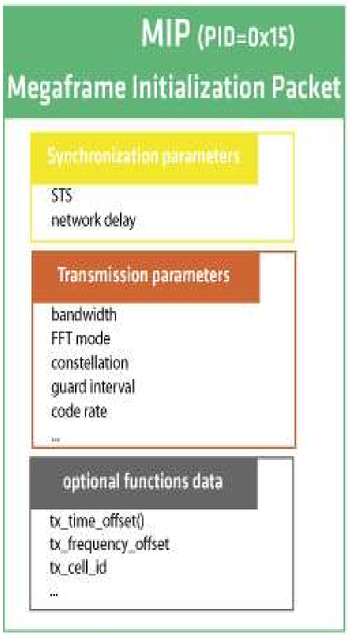
- ✔ **Transmission parameters**: Transmission parameters are also referred to as TPS (Transmission Parameters signalling) bits. Those TPS represent modulation settings (guard interval, bandwidth, FFT mode etc.).

  As regards to DVB-T, DVB-H added additional information: 4k mode, 5MHz bandwidth, in-depth interleaving, MPE-FEC and Time-Slicing TPS signalling;

- ✔ **Synchronization information**: Timestamp (STS: Synchronization TimeStamp) and time budget (maximum_network_delay). The meaning of these parameters is explained next paragraph;

- ✔ **Optional functions**: optional functions are aimed to address individually transmitters by means of their TxID enabling among other RF coverage refinement. For more information about this topic, please read our application note ''Addressing transmitters in a Single Frequency (SFN) Network'' (Application note on ENENSYS website).

The figure below illustrates in broad outline (left-side) the structure of the MIP packet (three main sections). Right-side shows the correspondence with the norm that specifies MIP insertion (ETSI EN 101 191).



Syntax	No. of Bits
mega-frame_initialization_packet () {	
transport_packet_header	32
Synchronization_id	8
section_length	8
pointer	16
periodic_flag	1
future_use	15
synchronization_time_stamp	24
maximum_delay	24
tps_mip	32
individual_addressing_length	8
for(i=0; i<N; i++) {	
tx_identifier	16
function_loop_length	8
for(i=0; i<N; i++) {	
function()	
}	
}	4
CRC32	32
for(i=0; i<N; i++) {	
stuffing_byte	8
}	

figure 3: Structure of MIP (Megaframe Initialization Packet)

MIP insertion and megaframe

The norm which specified MIP insertion defined a new group of packet, namely megaframe. The size of the megaframe depends on the code rate, as well as the constellation used.

The SFN Adapter forms a megaframe (n TS-packets), corresponding to 8 frames (or 2 super-frames) in 8k mode, 16 frames (or 4 super-frames) in 4k mode, and 32 frames (or 8 super-frames) in 2k mode. The number of RS-packets per super-frame is summed up below:

Code rate	*QPSK*			*16 QAM*			*64 QAM*		
	2K mode	4k mode	8k mode	2K mode	4k mode	8k mode	2K mode	4k mode	8k mode
½	252	504	1008	504	1008	2016	756	1512	3024
2/3	336	672	1344	672	1344	2688	1008	2016	4032
¾	378	756	1512	756	1512	3024	1134	2268	4536
5/6	420	840	1680	840	1680	3360	1260	2520	5040
7/8	441	882	1764	882	1764	3528	1323	2646	5292

Table 1: Number of RS-packets per Super-Frame

It is to note, for a given constellation and code rate, the size of the megaframe is independent from the FFT mode.

Megaframe time duration only depends on channel bandwidh and guard interval:

	Channel Bandwidth			
guard interval	8 MHZ	7 MHz	6 MHz	5 MHz
Δ / Tu = 1/32	0,502656 s	0,5744640 s	0,6702080 s	0,8042496 s
Δ / Tu = 1/16	0,517888 s	0,5918720 s	0,6905173 s	0,8286208 s
Δ / Tu = 1/8	0,5483520 s	0,6266880 s	0,7311360 s	0,8773632 s
Δ / Tu = ¼	0,6092800 s	0,6963200 s	0,8123733 s	0,9748480 s

Table 2: megaframe time duration

To sum up: the megaframe size depends on the code rate and constellation (independent from FFT mode used), the time duration is however determined based on channel bandwidth and guard interval.

One SFN Adapter/MIP inserter will insert exactly one MIP packet per megaframe (with dedicated 0x15 PID). The position of the MIP packet within the megaframe is signalled by the field '*pointer*' (see figure 1).

figure 4: Megaframe

Transmission parameters

Based on transmission parameters (tps_mip), SFN adapter will output exactly modulation bitrate. Before MIP insertion, input bitrate has thus to be lower than modulation datarate (otherwise, it will result in an overflow error).

Assuming input bitrate is ALWAYS lower than input bitrate, MIP inserter will thus perform MIP insertion and bitrate adapation.

Contrary to MFN where the transmitters have to perform this task, in SFN, transmitters will extract (parse MIP packet) transmission parameters from MIP packet and configure accordingly. The only task to achieve is thus synchronization since their input bitrate is stricly equal to output bitrate.

How is synchronization achieved ?

When talking about transmitters synchronization, two main synchronization criteria have to be taken into account:

1. **Temporal synchronization**: DVB-T/H Transmitters broadcasting synchronously, at the same time.
2. **Frequency synchronization**: Transmitters broadcast exactly the same set of sub-carriers.

Temporal synchronization

SFN adapter/MIP inserter's aim is to provide synchronization information to transmitters based on one common clock reference: GPS (Global Positionning System).

GPS is of course not used for localization purposes, but rather in order to provide both transmitters and SFN adapter with the following clock reference information:

- ✔ 1PPS (1 pulse per second signal)
- ✔ 10 MHz (derived from 1PPS signal)

Figure 2 illustrates clearly how temporal synchronization is achieved: For each megaframe output from SFN Adapter, STS (Synchronization Timestamp) is inserted (displayed in green color). STS is a reference time computed by the SFN Adapter relative to the last PPS received. The value is derived from 10 MHz counter, and ranges from 0 to 9,999,999 (100 ns step).

The last synchronization information transmitted is the network delay (namely *maximum_network_delay* in ETSI 101 191). This MIP information is the maximum time from SFN adapter/MIP inserter to reach any transmitter belonging to the SFN cell. Contrary to STS, maximum network delay value is static, and has to be evaluated carefully depending on distribution scheme used (MPEG2-TS over IP, satellite ...).

For all the transmitters, transmission time T_{trans} is thus defined as follows:

$$T_{trans}=(STS+maximum\_network\_delay) \text{ modulo } 10^7$$

Transmission time is modulo 10^7 since time reference basis is 1 second (1PPS derived from GPS clock reference).

As one can see, network delay for each transmitter is different (displayed in red, yellow and purple), but it does not exceed *maximum_network_delay*, which is a necessary condition for an SFN network to work properly !

Frequency constraint

As explained, 10 MHz clock reference is relevant to SFN synchronization (STS value). However, its rôle is not limited to temporal synchronization.

In DVB-T, DVB-H, DVB-SH, DAB, MediaFLo etc. the modulation schem used is the COFDM modulation which enables to cope with multi-path fading. A large number of carriers is used to carry the information.

The (common) accuracy of 10 MHz will guarantee any transmitter belonging to one SFN cell to broadcast exactly the same set of sub-carriers (same frequency, no frequency shift).

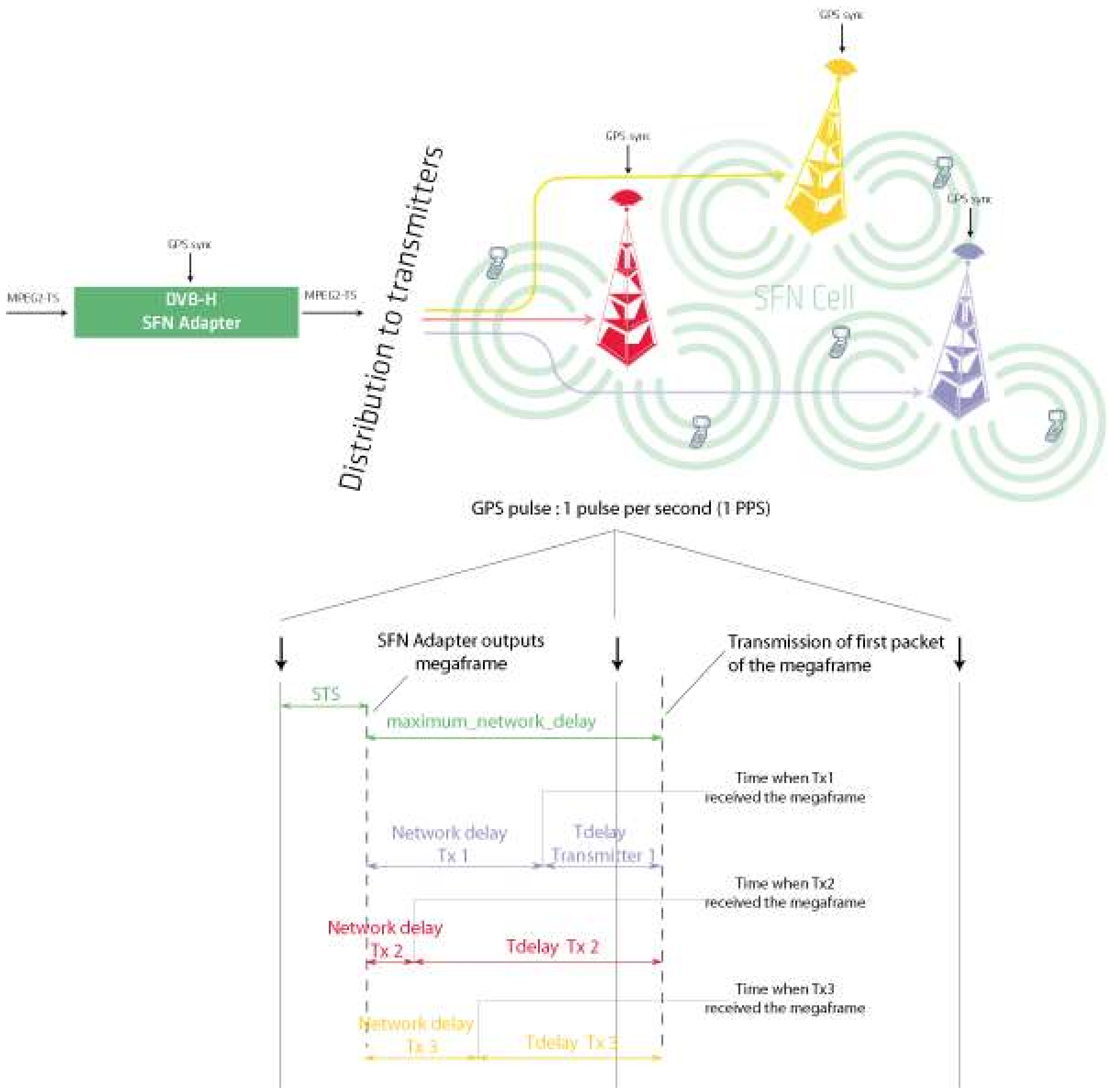


figure 5: SFN Synchronization

Conclusion

Optimizing spectrum and bandwidth is made possible with Single Frequency Network topology: all the transmitters will radiate synchronously based on information provided by Single Frequency Network (SFN) adapter.

Two kinds of synchronization are in use: temporal (1PPS + 10 MHz) and frequency (10 MHz). The more accurate those references are, the more precise RF coverage is.

It is to be noted an inaccuracy of frequency synchronization (10 MHz) will result in very bad RF coverage (strong Inter-carriers interferences). The use of optional functions can be a solution for correcting such an inaccuracy.