MulteFire in 1.9 GHz

MULTEFIRE®

I. Introduction

1. Overview of MulteFire in 1.9 GHz

a. Existing Technologies in 1.9 GHz Spectrum

In 1.9 GHz spectrum, DECT (Digital Enhanced Cordless Telecommunication) systems have been widely deployed in more than 100 countries [1]. PHS (Personal Handy-phone System) is only deployed in Japan and the service for general use will be ended in July 2020. The 3rd Generation Partnership Project (3GPP) Time Division Long Term Evolution (TD-LTE) Band 39 system has only one network deployed in China by China Mobile, but more than 1400 types of LTE terminals all over the world support Band 39[2].

b. Design Targets and Requirements of MulteFire in 1.9 GHz

MulteFire® is a new, innovative technology designed to create new wireless networks by operating LTE technology standalone in unlicensed and shared or shared spectrum. The MulteFire Release 1.0 specification was completed in January 2017 by the MulteFire Alliance. The MulteFire Alliance is an open, international organization dedicated to support the common interests of its members, developers and users in the application of LTE and next generation mobile cellular technologies in configurations that use only unlicensed radio spectrum.

To fully utilize the legacy LTE ecosystem, which can largely reduce the system cost and achieve quick time-to-market, the key target of MulteFire in 1.9 GHz is to reuse the existing Band 39 terminals. Furthermore, minor modification at the eNodeB side is needed to obtain co-existence with DECT and PHS systems. MulteFire in 1.9 GHz can operate anywhere with no need of extra costly spectrum or specialists in network deployments. To deliver high performance, seamless mobility and resilience network, many legacy sophisticated LTE features are reused in 1.9 GHz MulteFire systems, e.g. frame structure, modulation, link adaptation and mobility, etc.

c. Deployment Use Cases for MulteFire in 1.9 GHz

Similar to PHS and DECT systems, one of the targeted deployment scenarios for MulteFire in 1.9 GHz is to provide enhanced cordless phone services within enterprises, private and public venues. Voice services within enterprises can be operated within MulteFire networks. MulteFire networks can also be used as RANs (Radio Access Networks) to provide connectivity to PSTN (Public Switched Telephone Network) via PBX (Private Branch eXchange) and provide dial-in and dial-out phone calls outside enterprises in the same ways as LTE RANs.

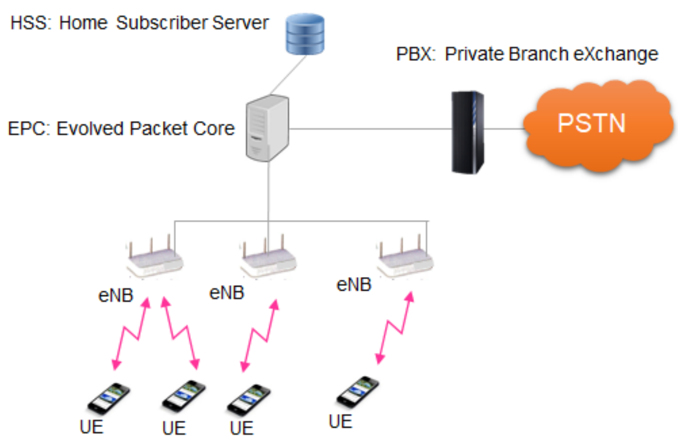

Figure 1. Enhanced Office Cordless Telephone System

Besides voice and data services, various IoT (Internet of Things) and M2M (Machine to Machine) services can also be supported by MulteFire in 1.9 GHz. Band 39 LTE terminals can also be used for IoT services which have high data requirements (e.g. more than 5 Mbps). The Band 39 Cat.0 and eMTC (enhanced Machine Type Communication) terminals can support IoT services with medium data rate requirement (e.g. less than 1 Mbps). In the near future, Band 39 NB-IoT (Narrow Band - Internet of Things) terminals will also be utilized to extend IoT services with low data rate requirements (e.g. less than 100Kbps) and further reduce the UE power consumption.

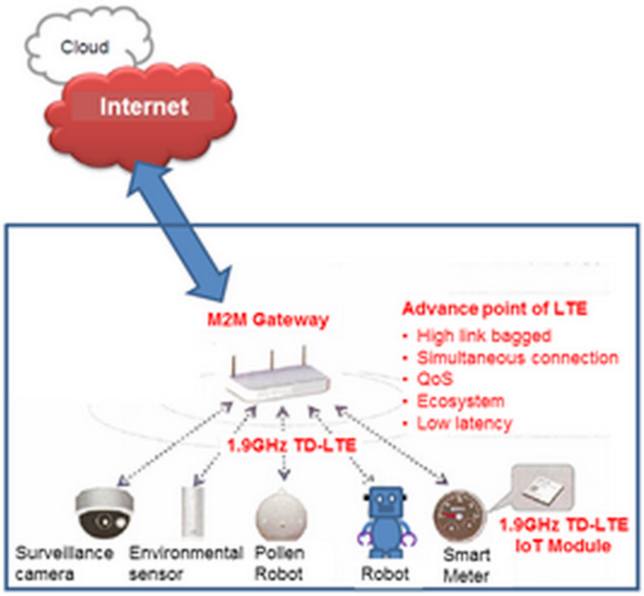

Figure 2. Evolution of M2M & IoT Solutions

d. Sharing the Existing Cellular EcoSystem by Reusing the Existing Terminals

MulteFire in 1.9 GHz expands the MulteFire technologies to 1.9 GHz spectrum, which can reuse the existing TD-LTE device ecosystem and shorten time-to-market. Today, commercial end-to-end products of MulteFire in 1.9 GHz are now available and have passed the TELEC (Telecom Engineering Center) certification in Japan. Many trials and demonstrations are organized by potential big customers, e.g. enterprises and universities.

II. Technical Features of MulteFire in 1.9 GHz

1. Waveform and Frame Structure

MulteFire in 1.9 GHz only support normal CP (Cyclic Prefix) and reuses the 3GPP TD-LTE waveform and frame structure. For downlink and uplink transmission, the waveform is OFDMA (Orthogonal Frequency Division Multiplexing Access) and SC-FDMA (Single Carrier Frequency Division Multiple Access), respectively. Because the symmetric downlink and uplink frame structure is used in DECT systems, MulteFire in 1.9 GHz only use symmetric downlink and uplink frame structure. For example, Downlink-Uplink configuration 1 in frame structure type 2 can be configured and the guard period in special subframe should be larger than or equal to 643us, which means special subframe configurations 0 and 5 can be used.

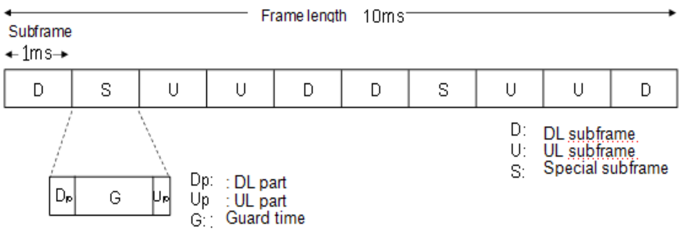

Figure 3. Frame Structure for MulteFire in 1.9GHz

2. Listen-Before-Talk (LBT) at the Network Side

The detailed LBT procedures are shown in the figure below. Type 1 LBT (LBT1) should be done by the eNodeB before the cell turns on to sense for channel idle. If yes, the eNodeB can set the power level and continuously transmit for a period of T1. If no, the channel will be back off for DECT and the eNodeB will do LBT1 again until the channel is clear. After the eNodeB turns on the cell, type 2 LBT (LBT2) should be done before eNodeB schedule PUSCH transmission in corresponding uplink subframes. After T1 expires, the eNodeB need to do both LBT1 and LBT2 again to allow for further operation.

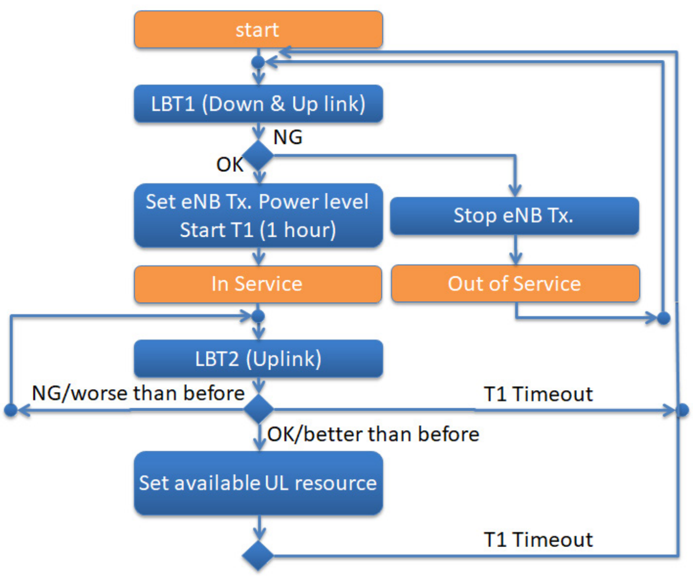

Figure 4. Detailed LBT Procedures at the Network Side

a. LBT1 Before Cell ON

eNodeBs must perform LBT1 before attempting to emit radio at the target frequency and bandwidth. After sensing the channel is idle during LBT1, the eNodeB can continuously transmit for a period T1, and after T1 expires, the eNodeB shall do LBT1 again. If only DECT systems are allowed by the regulation in certain country, the LBT1 equals to 20ms. If both DECT and PHS systems are allowed by the regulation, LBT1 for PHS (LBT1-PHS) is also needed. In Japan, the eNodeB has to do LBT1-PHS at the frequency of control channels of private PHS (limited only to 1898.45 MHz and 1900.25 MHz with 300 KHz bandwidth currently) and the sensing duration of PHS system LBT1-PHS is 300ms. The transmission period T1 is one hour after the eNodeB passes the LBT1 and LBT1-PHS.

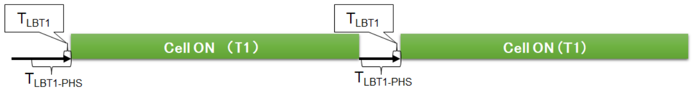

Figure 5. LBT1 Before eNB Transmission

For LBT1 and LBT1-PHS, eNB shall set the energy detection threshold (X_{Thresh}) to be less than or equal to the maximum energy detection threshold X_{Thresh_max} is determined as follows:

$$X_{\text{Thresh\_max}} = X_r + \min\left\{ \begin{array}{l} \min\{P_{MAX\_eNB} - P_{TX\_eNB}, 20dB\}, \\ \min\{P_{MAX\_UE} - P_{TX\_UE}, 20dB\} \end{array} \right\}.$$

Where:

- X_r is minimum energy detection threshold defined by regulatory requirements in dBm
- P_{MAX_eNB} is the maaximum allowed eNB output power defined by regulatory requirements in dBm
- P_{MAX_UE} in the maximum allowed UE output power defined by regulatory requirements in dBm
- P_{TX_eNB} is the actual eNB output power in dBm
- P_{TX_UE} is the actual maximum output power among all UEs in dBm

In Japan, the parameters defined by regulatory requirements [3] ae listed in the table below.

	P_{MAX_eNB}	P_{MAX_UE}	X_r for LBT1	X_r for LBT1-PHS
5MHz system	23dBm	20dBm	-64dBm	-82dBm
1.4MHz system	20dBm	20dBm	-68dBm	-75dBm

Table 1. Parameters Defined by Regulatory Requirements for LBT1 and LBT1-PHS

b. LBT2 before PUSCH Scheduling after Cell ON

After the eNodeB turns on the cell, LBT2 should be done before the eNodeB schedules PUSCH (Physical Uplink Shared Channel) transmission in corresponding uplink subframes. Within a sensing duration LBT2 = 20ms, if the channel is idle at corresponding uplink subframes, the eNodeB can schedule PUSCH transmission in corresponding uplink subframes before T1 expires. The LBT2 is mainly used for measuring signal strength of a co-existing DECT system. One frame in DECT system is 10ms and contains 24 slots. Slot 0-11 are used for downlink transmission and slot 12-23 are used for uplink transmission. Paired downlink and uplink slots are used in DECT system, which means if slot 0 has downlink transmission then slot 12 has uplink transmission. As shown in the figure below, if the detected energy at any subframe of subframes #2, #7 at first frame and second frame is above the threshold, the eNodeB should not schedule PUSCH at subframe #2, #7 in the following frames and can continuously do the LBT2.

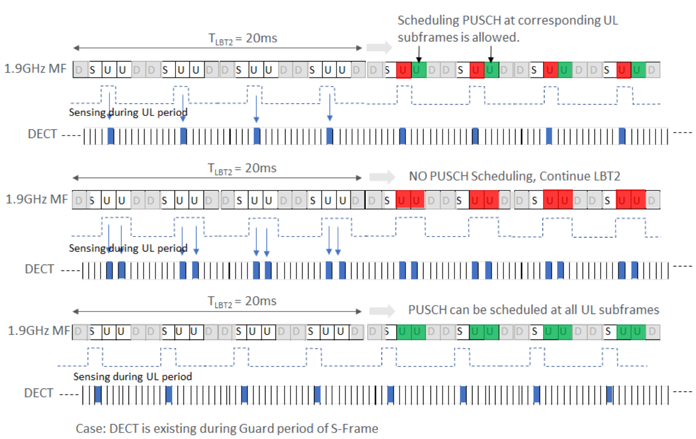

Figure 6. LBT2 before PUSCH Scheduling

For LBT2, the equation of maximum energy detection threshold is same to that of LBT1. In Japan, the parameters defined by regulatory requirements are listed in the table below.

	P_{MAX_eNB}	P_{MAX_UE}	X_r for LBT2
5MHz system	23dBm	20dBm	-64dBm
1.4MHz system	20dBm	20dBm	-68dBm

Table 2. Parameters Defined by Regulatory Requirements for LBT2

c. Network Deployment and IMSI Management

In Japan, all MulteFire in 1.9 GHz networks share the same PLMN (Public Land Mobile Network), which is similar to the PLMN Access Mode described in the MFA TS MF.201 [4]. In order to distinguish different private networks, TAC (Tracking Area Code) will be used and assigned per private network. If the UE is rejected to access to a certain eNodeB, it does not try to connect to those eNodeBs which have the same TAC.

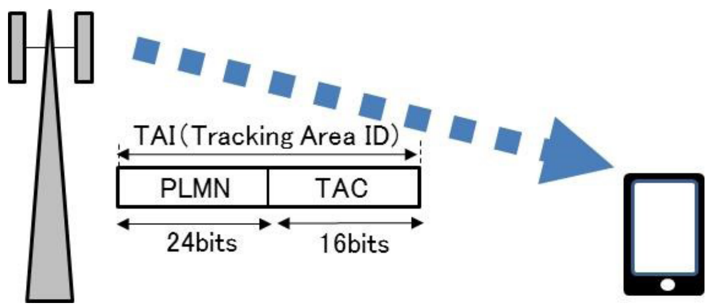

Figure 7. Separation of private networks

For IMSI (International Mobile Subscriber Identity) management in Japan, different vendors keep a unique set of IMSI numbers by encoding vendor code in MSIN (Mobile Subscriber Identification Number). A third-party organization will maintain the vendor code assignment.

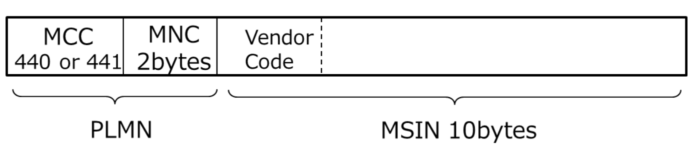

Figure 8. IMSI Management of 1.9 GHz MulteFire networks in Japan

III. Performance of MulteFire in 1.9 GHz

1. Co-Existence Performance Evaluation

In Japan, co-existence study about common frequency use of 1.9 GHz MulteFire system, a DECT system and PHS system were evaluated [5] considering three different deployment models and all models show that the call failure rate is less than 1%. This means that co-existence between 1.9 GHz MulteFire system, DECT system and PHS system can be achieved.

Considered Model	Call Failure Rate		
I:high density home	PHS	DECT	1.9 GHz MF (1.4M)
	1.45E-15	3.88E-08	5.42E-03
	PHS	DECT	1.9 GHz MF (5M)
	1.45E-15	3.20E-06	2.18E-12
II:high density office	PHS	DECT	1.9 GHz MF (1.4M)
	5.66E-09	6.69E-05	7.68E-02
	PHS	DECT	1.9 GHz MF (5M)
	5.66E-09	1.09E-03	3.80E-08
III: in office high density in one room	PHS	DECT	1.9 GHz MF (1.4M)
	1.44E-05	2.84E-04	6.69E-05
	PHS	DECT	1.9 GHz MF (5M)
	1.44E-05	1.09E-03	1.11E-38

Table 3. Co-Channel Co-Existence Results

1. Co-Existence Lab Test

MulteFire coexistence with DECT can also be seen in Figure 9, where a live DECT call and active MulteFire share the band in a demo [6]. On the left-hand side of the picture we observe the UL (2.5Mb/s) and DL (5Mb/s) data rates, on the right top the channel utilization is demonstrated and on the right bottom we see the spectrum sharing – the left "peaky" curve is DECT and right "flattish" curve is MulteFire.

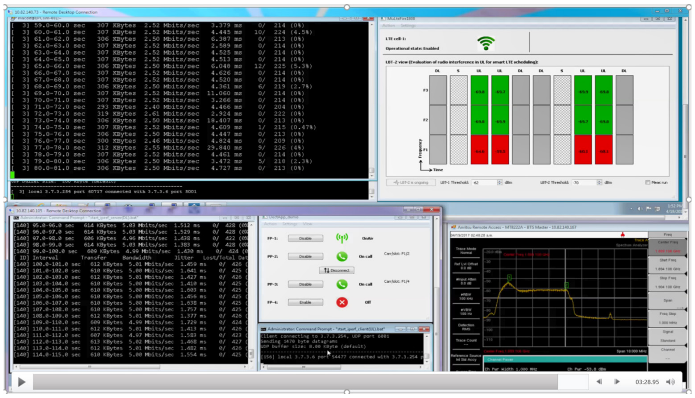

Figure 9. Live demo on DECT-MulteFire sharing

IV. Conclusion and Future Work

MulteFire Release 1.1 expands MulteFire technologies to 1.9 GHz spectrum, which can reuse the existing TD-LTE device ecosystem and shorten time-to-market. At the network side, LBT functions are added on top of an TD-LTE system and can achieve co-existence with incumbent systems. Moreover, MulteFire in 1.9 GHz system achieves higher peak data rate by higher modulation order and wider bandwidth compared to PHS and DECT systems. Finally, IoT use cases can also be supported by MulteFire in 1.9 GHz via Cat. 1 or Cat.0 LTE UEs now or by eMTC and NB-IoT UEs in the future, which enlarges the potential market size.

Currently, commercial products of MulteFire in 1.9 GHz in Japan are already available and have passed the TELEC certification. Many trials and demos are organized by potential big customers. The MulteFire Alliance is now drafting interoperability test specifications to ensure the system performance and the formal test program will be finalized and published by Q2 of 2019. Besides the Japanese market, the MulteFire Alliance is also driving to bring MulteFire 1.9 GHz technology to other regions which have similar regulations to Japan.

References

[1] ETSI DECT HomePage
[2] GSA LTE Ecosystem Report April 2017
[3] A-GN6.00-01-TS, XGP Forum Document, sXGP (shared XGP) Specification
[4] MulteFire Alliance, Architecture for PLMN Access Mode (Stage 2), MFA TS MF.201
[5] No. 35-3-2, Summary Report from Land Mobile Communication Community of MIC
[6] Demo on MF-DECT spectrum sharing, MulteFire open day, New Jersey April 2017

Glossary of Terms

3GPP – Third Generation Partnership Project
CP – Cyclic Prefix
DECT – Digital Enhanced Cordless Telecommunication
eMTC – enhanced Machine Type Communication
IMSI – International Mobile Subscriber Identity
IoT – Internet of Things
LBT – Listen Before Talk
LTE – Long Term Evolution
M2M – Machine to Machine
MF – MulteFire
MSIN – Mobile Subscriber Identification Number
NB-IoT – Narrow Band Internet of Things
OFDM – Orthogonal Frequency Division Multiplexing Access
PBX – Private Branch eXchange
PHS – Personal Handy-phone System
PLMN – Public Land Mobile Network
PSTN – Public Switched Telephone Network
PUSCH – Physical Uplink Shared Channel
RAN – Radio Access Network
SC-FDMA – Single Carrier Frequency Division Multiple Access
TAC – Tracking Area Code
TELEC – Telecom Engineering Center

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