스마트그리드 FAN 무선통신 표준기술 현황과 전망

한국전력공사 강 동 훈

2021. 11. 11.

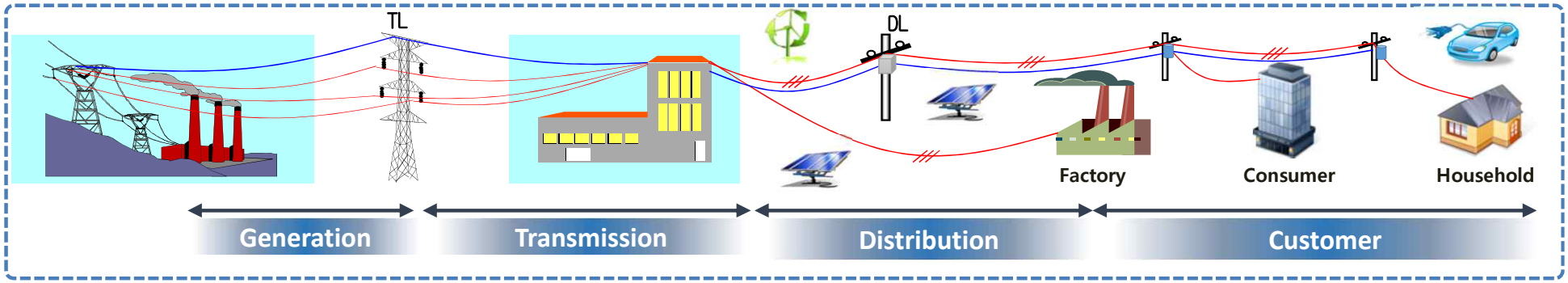
GISC2021
Global ICT Standards Conference

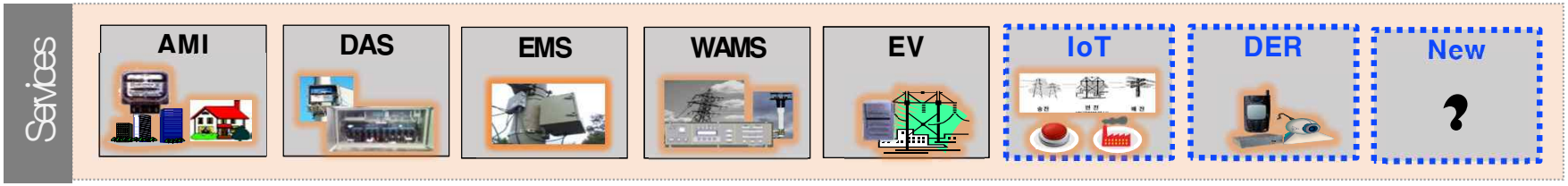
KEPCO

1. Needs for Proposed Standard

Use cases

Smart Grid





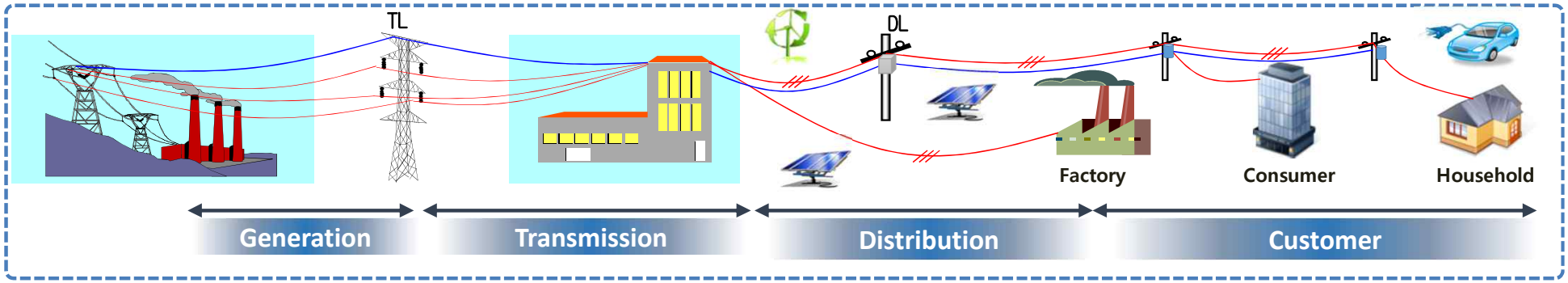
Requirements for Smart Grid

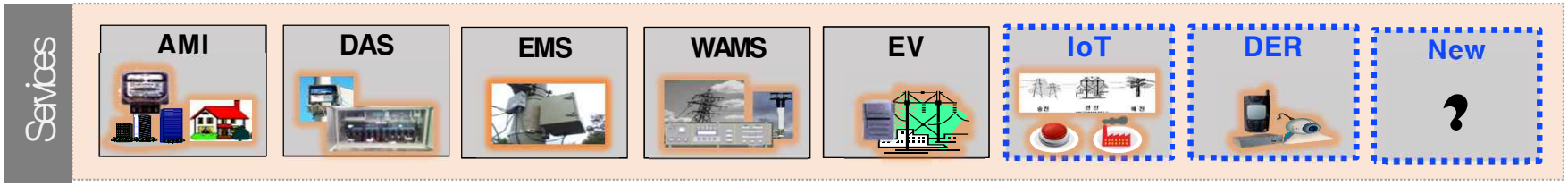
Application	Network Requirements (Ref. by Department of Energy)			
	Throughput	Latency	Reliability	Security
Smart Grid	10 ~ 100kbps per node	20ms ~ 15s	99~99.999%	High

1. Needs for Proposed Standard

Use cases

Smart Grid





Communication methods of Smart Grid

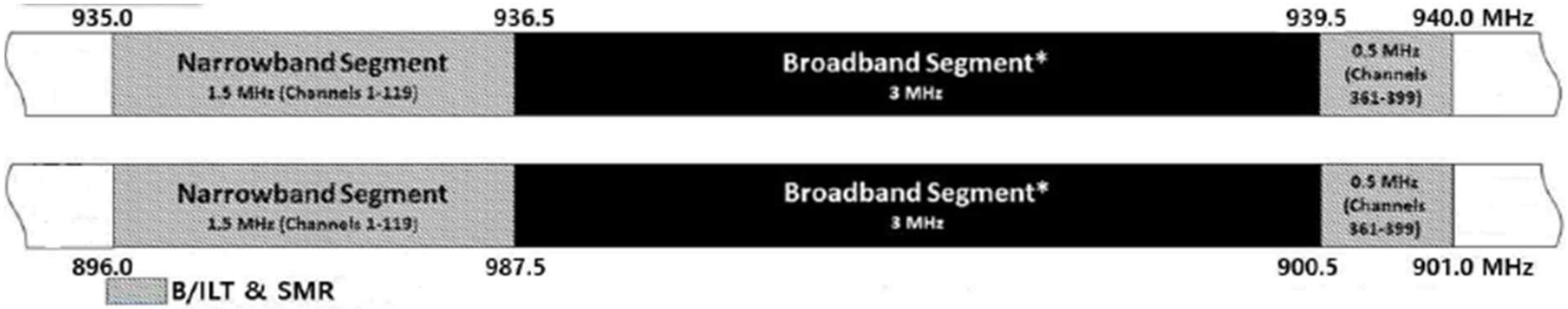
Classification	Wired Network	Wireless Network
Power Control	Optical	TRS (380 ~399.9 MHz)
Smart Metering	PLC, HPGP	Wi-SUN (917 ~ 923.5MHz)
		LTE (800MHz, 900MHz, 1.8GHz, 2.1GHz, 2.6GHz)
New and Renewable Power Generation	Optical	TRS (380 ~ 399.9MHz)

1. Needs for Proposed Standard

Considering Spectrums for Smart Grid

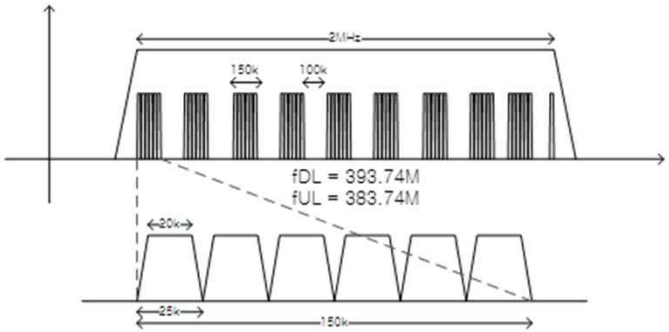
Spectrum policy(Industrial licensed band)

- USA FCC: 12.5kHz bandwidth for 900MHz spectrums

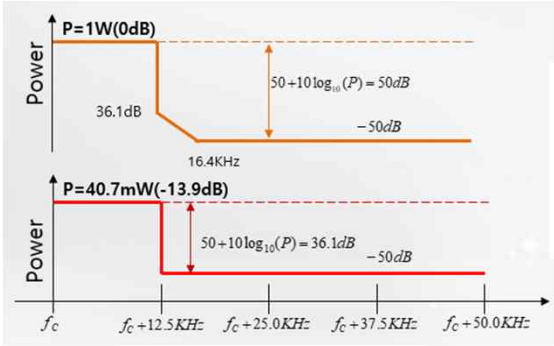


USA 900Mhz spectrums (from FCC)

- Korea: 25kHz bandwidth for 300/800/900MHz spectrums (380MHz band is allocated for KEPCO)



Korea 380MHz spectrums



Spectrums Regulation

- UK Ofcom: 12.5kHz/25kHz bandwidth for 123/420MHz spectrums
- Ireland ComReg: 12.5kHz bandwidth for 156/450MHz spectrums
- Hongkong COMS: 12.5kHz/25kHz bandwidth for 70/460MHz spectrums
- QATAR MOTC: 12.5kHz bandwidth for 30/150/360MHz spectrums

1. Needs for Proposed Standard

Candidate RAT to support Smart Grid (narrowband technology)

Bandwidth and peak rate for current narrowband technology

- No technology satisfies 100Kpbs peak rate with bandwidth≤25kHz

Technology	TRS APCO P25	TRS TETRA	3GPP LTE-M	3GPP NB-IoT
Occupied Bandwidth	12.5kHz, 6.252kHz	25kHz	1.08MHz	180KHz
Peak Rate	9.6Kpbs	36Kpbs	1Mpbs	200Kpbs
Licensed/ Unlicensed	Licensed band	Licensed band	Licensed band	Licensed band

Requirements for current narrowband technology

Method for Digital TBS	APCO P25	TETRA
Standardization	Phase 2	Phase 2
Frequency spectrums (MHz)	120~300, 360~512, 800~941	380~400, 410~430, 450~470, 870~888, 915~933
Occupied bandwidth	12.5kHz(C4FM), 6.252kHz(CQPSK)	25KHz (4 slots)
Multiple access scheme	FDMA	TDMA
Peak rate	9.6Kpbs	36Kpbs

Requirements for TRS technology

	Release 8	Release 8	Release 12	Release 13	Release 13
	Cat. 4	Cat. 1	Cat. 0	"Cat. 1.4MHz"	"Cat. 200kHz"
Downlink peak rate	150 Mbps	10 Mbps	1 Mbps	1 Mbps	200 kbps
Uplink peak rate	50 Mbps	5 Mbps	1 Mbps	1 Mbps	144 kbps
Number of antennas	2	2	1	1	1
Duplex mode	Full duplex	Full duplex	Half duplex	Half duplex	Half duplex
UE receive bandwidth	20 MHz	20 MHz	20 MHz	1.4 MHz	200 kHz
UE transmit power	23 dBm	23 dBm	23 dBm	20 dBm	23 dBm
Modem complexity	100%	80%	40%	20%	<15%

Requirements for 3GPP LTE technology

1. Needs for Proposed Standard

Candidate RAT to support Smart Grid (narrowband technology)

Bandwidth and peak rate for current narrowband technology

- No technology satisfies 100Kpbs peak rate with bandwidth≤25kHz

Technology	IEEE Wi-Sun	LoRa	SigFox
Occupied Bandwidth	180KHz	125KHz	0.1kHz
Peak Rate	50Kpbs	5Kpbs	100bps
Licensed/ Unlicensed	Unlicensed band	Unlicensed band	Unlicensed band

Requirements for current narrowband technology

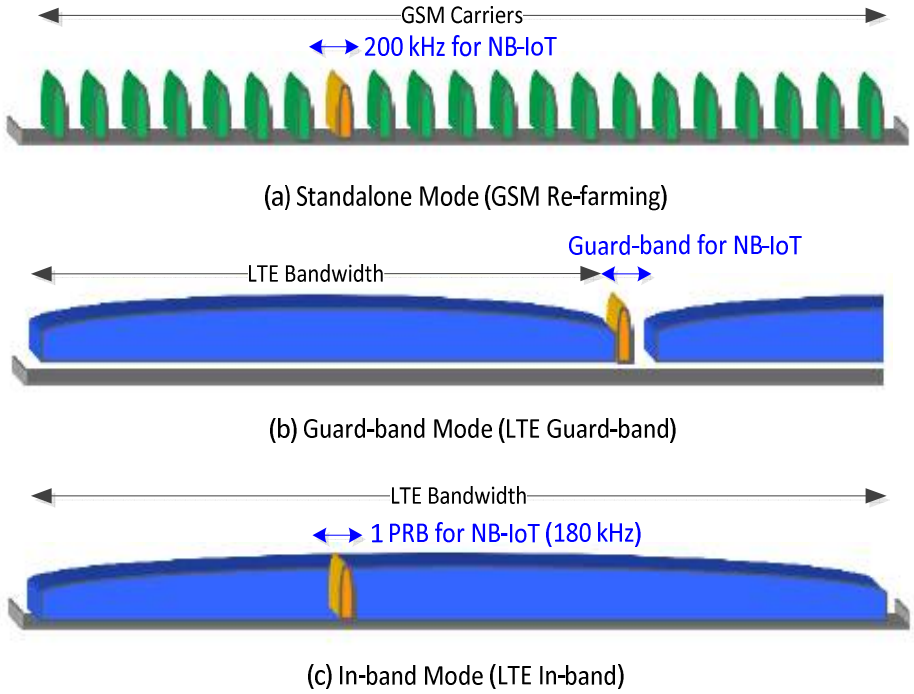
3GPP NB-IoT – Scenario/Requirement

Scenarios (focused on objectives) [1]

- improved indoor coverage
- support for massive number of low throughput devices
- low delay sensitivity
- ultra-low device cost
- low device power consumption and (optimized) network architecture

Scenarios (focused on operations) [1]

- Stand-alone operation
  utilizing for example the spectrum currently being used by GERAN systems as a replacement of one or more GSM carriers, as well as scattered spectrum for potential IoT deployment
- Guard band operation
  utilizing the unused resource blocks within a LTE carrier's guard-band
- In-band operation
  utilizing resource blocks within a normal LTE carrier



Requirements

- 180kHz UE RF bandwidth for both DL and UL (c.f. LTE-M: 1.08MHz)
- 200Kbps (c.f. LTE-M: 1Mbps)

3GPP NB-IoT PHY – Waveform/Multiple Access Scheme

Waveform/Multiple Access Scheme

- DL(downlink): OFDMA (c.f. LTE: OFDMA, NR: OFDMA)
- UL(uplink): SC-FDMA (c.f. LTE: SC-FDMA, NR: OFDMA/SC-FDMA)
- SL(sidelink): Not Supported (c.f. UL resources are used for LTE/NR SL)

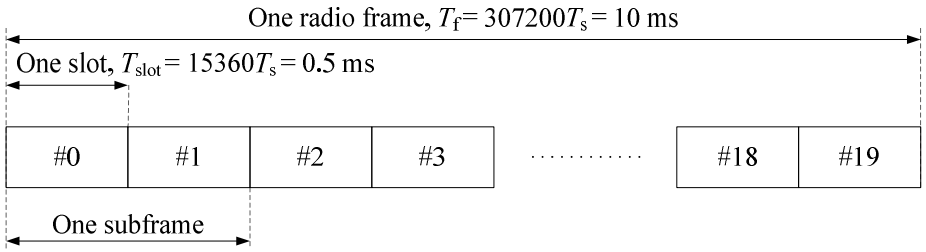
3GPP NB-IoT PHY – Numerology, Frame structure, Duplex

Numerology

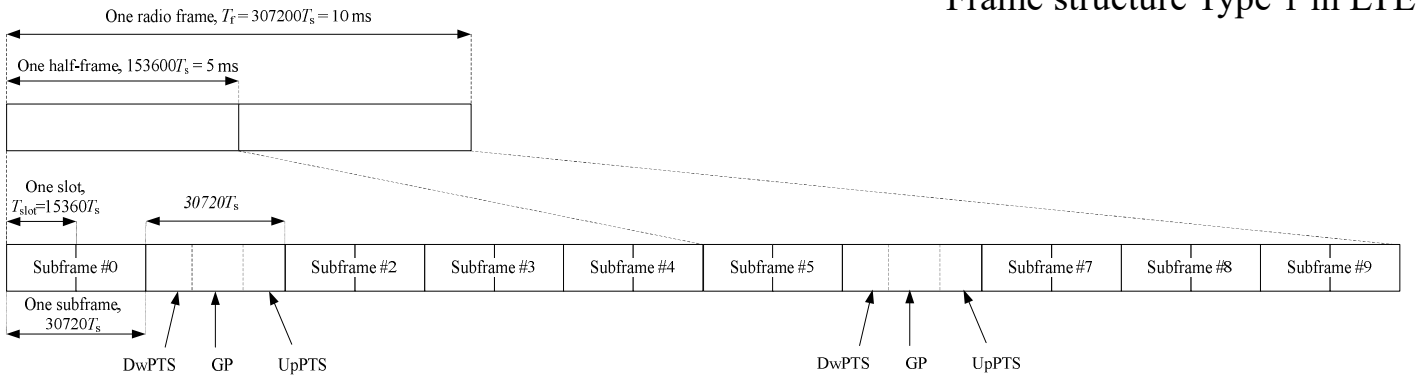
- DL: 15kHz SCS(sub-carrier spacing)
- UL: 15kHz/3.75kHz SCS

Frame structure

- Same to the LTE



Frame structure Type 1 in LTE (for FDD) [2]



Frame structure Type 2 in LTE (for TDD) [2]

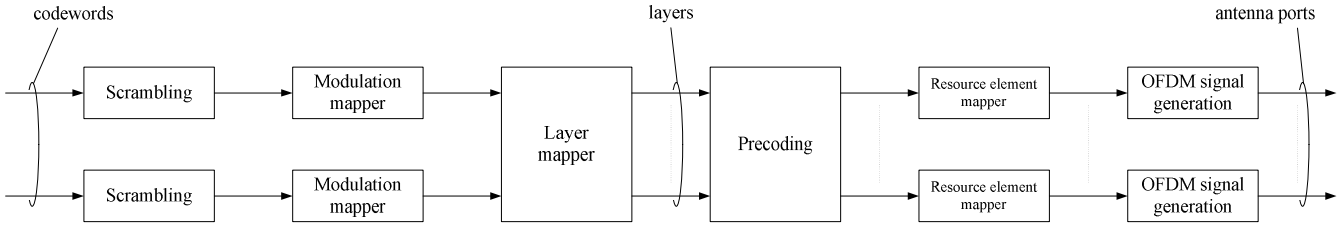
Duplex

- Only half duplex operations are supported

3GPP NB-IoT PHY – Tx/Rx structure

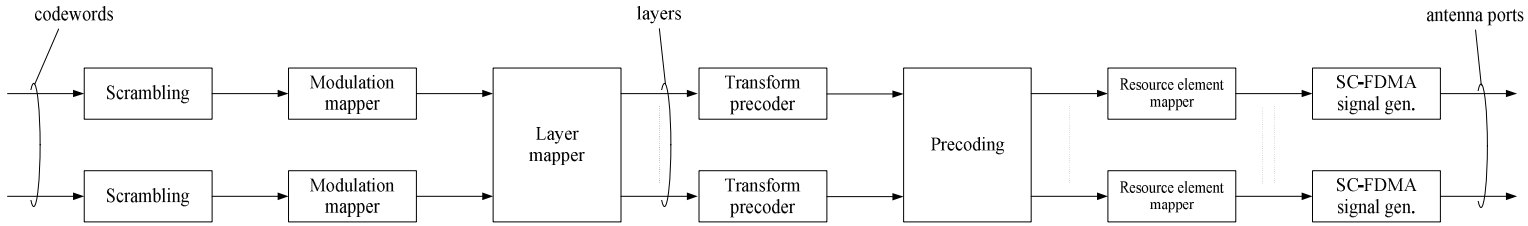
DL physical channel processing [2]

- Same to the LTE



UL physical channel processing [2]

- Same to the LTE

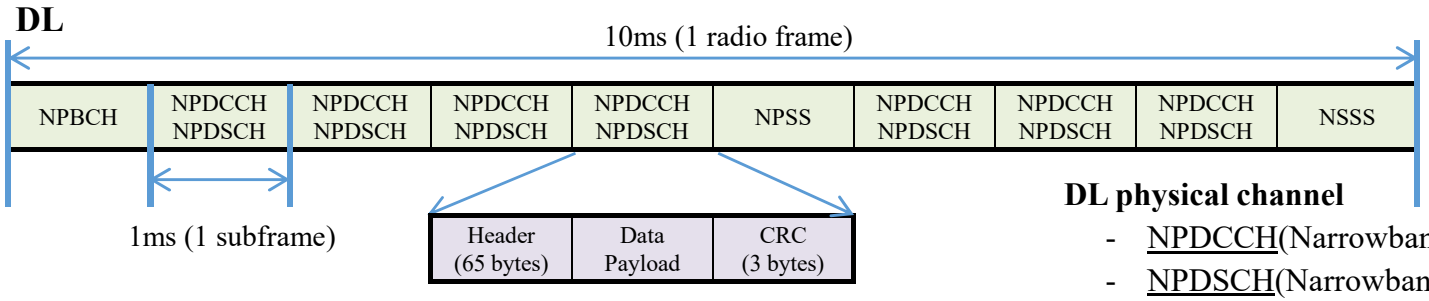


3GPP NB-IoT PHY – Physical Channels/Signals (1)

Channels

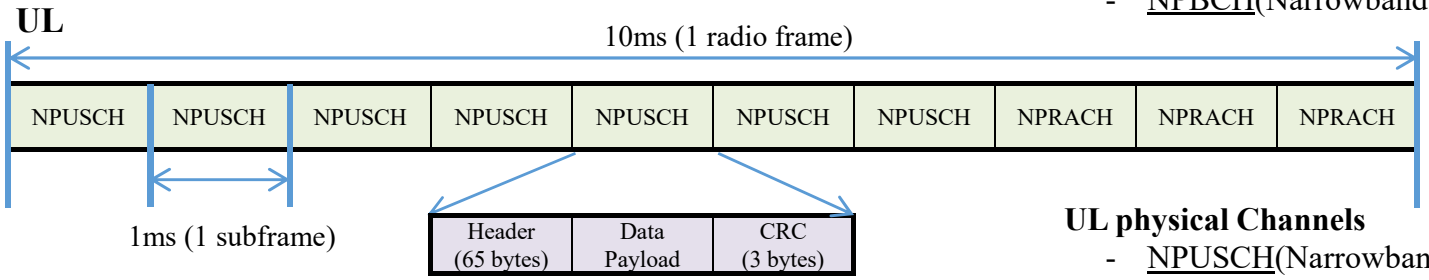
- DL Channels: NPDCCH, NPDSCH, NPBCH
- UL Channels: NPUSCH, NPRACH
- DL Signals: NPSS/NSSS, NRS, NPRS, NWUS
- UL Signals: NDMRS

3GPP NB-IoT PHY – Physical Channels/Signals (2)



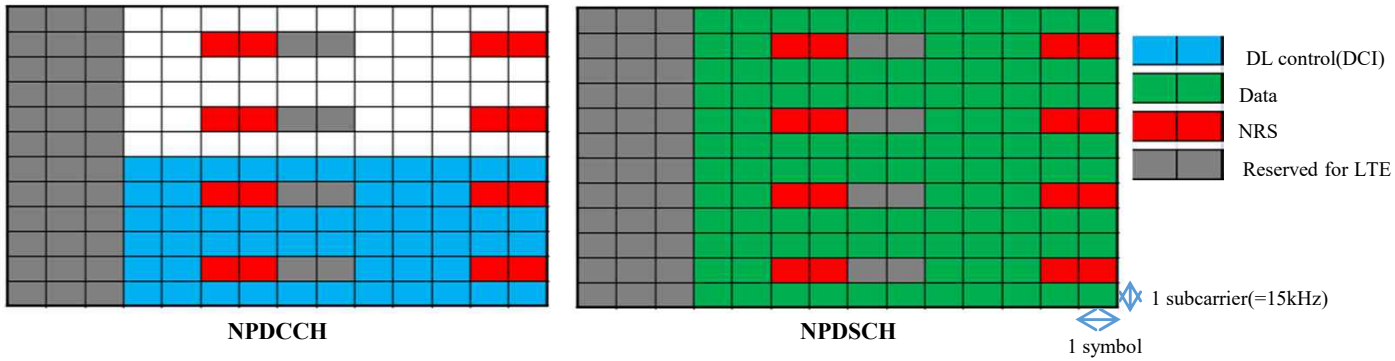
DL physical channel

- NPDCCH(Narrowband Physical Downlink Control Channel)
- NPDSCH(Narrowband Physical Downlink Shared Channel)
- NPBCH(Narrowband Physical Broadcast Channel)



UL physical Channels

- NPUSCH(Narrowband Physical Uplink Shared Channel)
- NPRACH(Narrowband Physical Random-Access Channel)



DL/UL physical Signals

- NPSS/NSSS(Narrowband Primary/Secondary Synchronization Signal)
- NRS(Narrowband Reference Signal)
- NPRS(Narrowband Positioning Reference Signal)
- NWUS(Narrowband Wake Up Signal)
- NDMRS(Narrowband Demodulation Reference Signal)

3. New Proposal (overall)

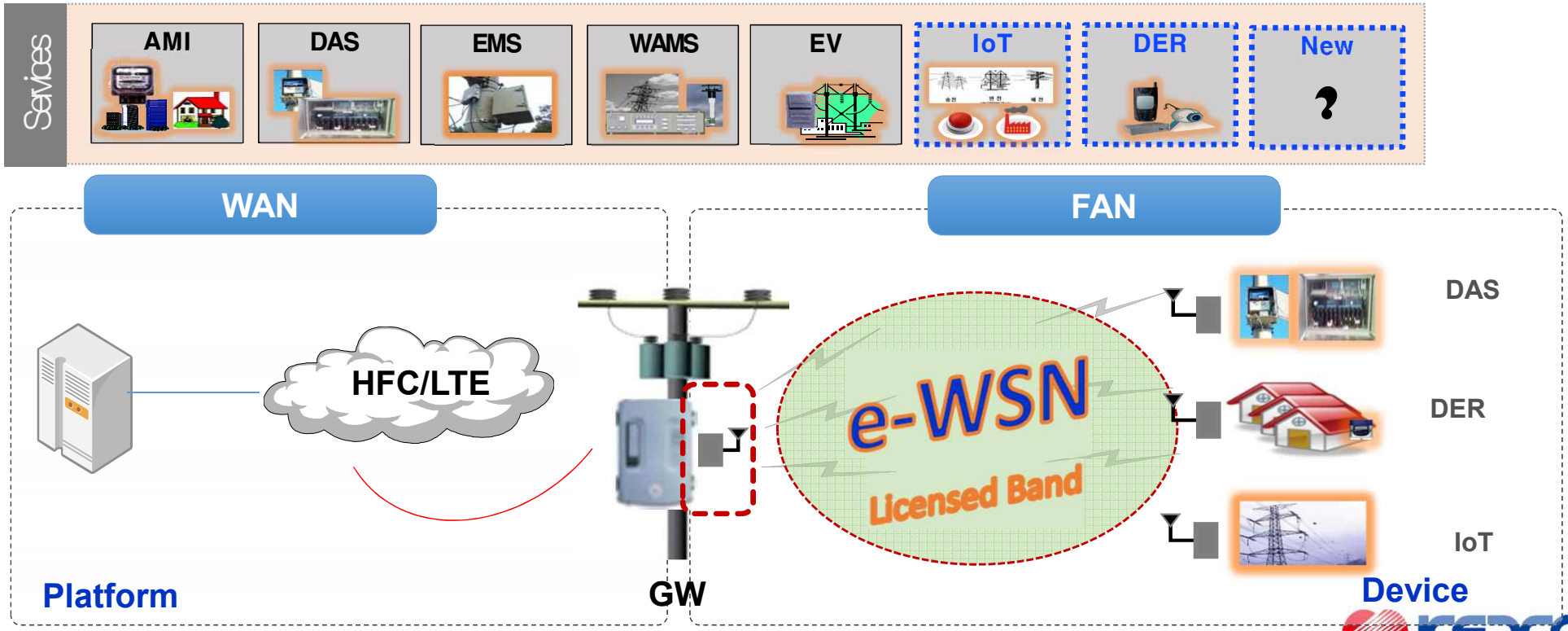
Requirements for proposed Standard

- Throughput: 10 ~ 100kbps per node
- Latency: 20 ms (PHY – TBD)
- Reliability: 99% (PHY – TBD)

NOTE) It is not necessary to satisfy all of the above requirements at the same time

Objectives for proposed Standard

Development of Robust Wireless Sensor Network based on licensed band for Field Area Network



3. New Proposal (overall)

The Solutions for the Requirements

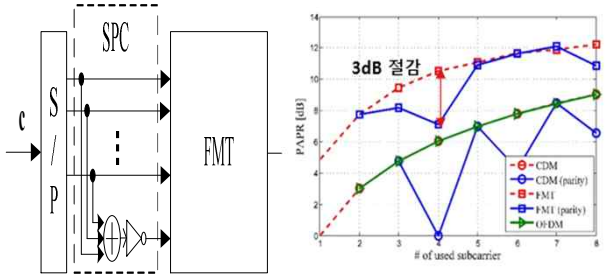
1 MCS table design

- For reliability : BPSK & 1/2 Coding ➔ 7.5kbps
- For throughput : 64QAM & 1 Coding ➔ 135kbps

MCS	Modulation Level	Coding rate	Data rate [kbps]
0	BPSK	1/3	**7.5**
1	BPSK	1/2	11.25
6	64QAM	2/3	90
7	64QAM	5/6	112.5
8	**64QAM**	1	**135**

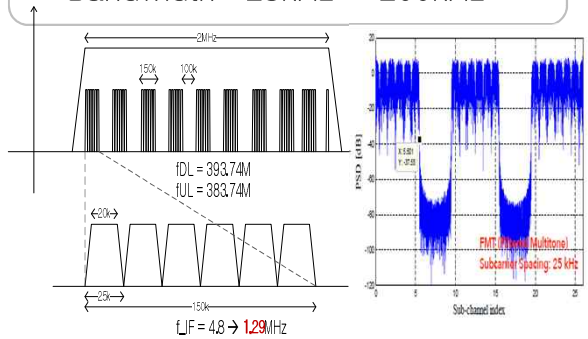
2 Solution for PAPR

- Using Single Parity Check, PAPR 3dB reduction could be achieved.



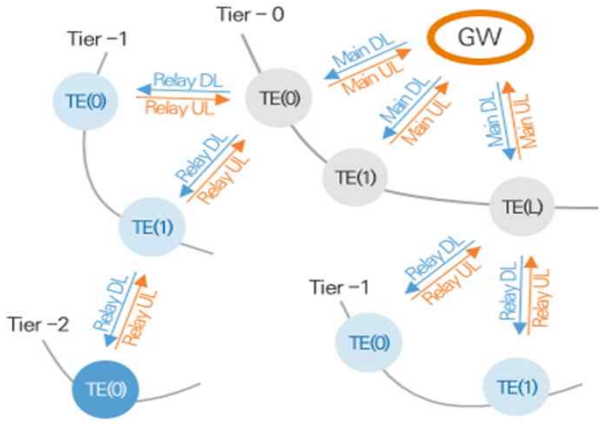
3 New Waveform

- Filtered Multi-Tone (FMT)
- Bandwidth : 25kHz ~ 200kHz



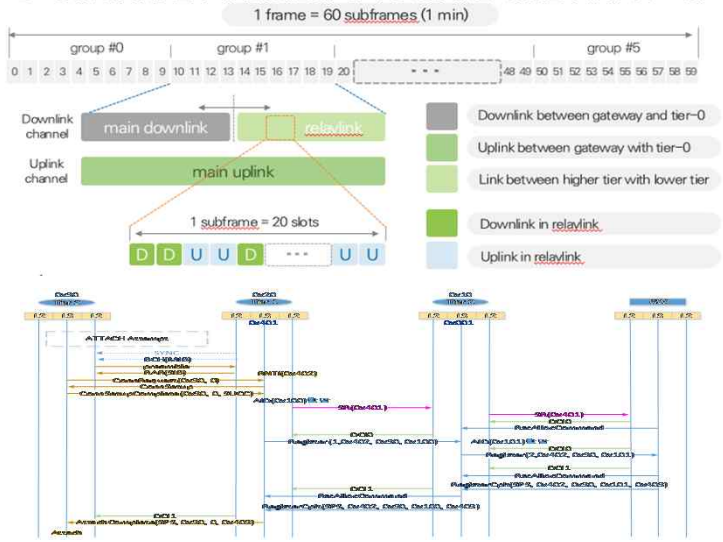
4 Relay for coverage hole

- Support multi-hop
- Introduce dedicated slot for relay



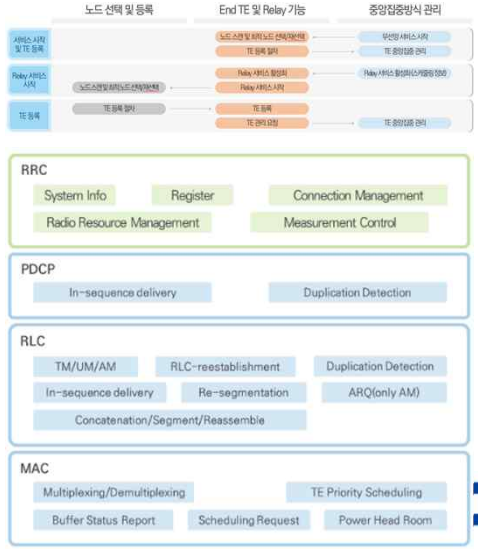
5 Frame structure for latency reduction

- Packet Block size is 10ms
- Support TDMA/FDD/TDD (including Full Duplex)
- Introduce Emergency Tx Mode (like URLLC in



6 Channel Design

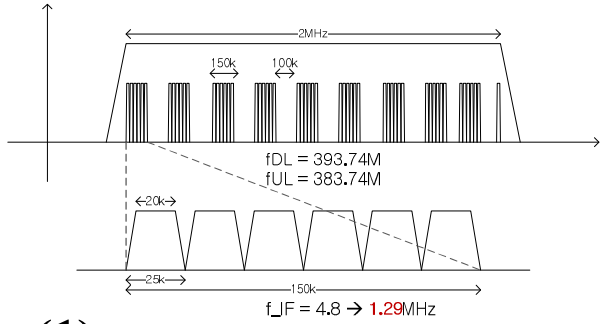
- CP / UP based operation
- CP: RRC / UP: PDCP, RLC, MAC



eWSN PHY – Waveform/Multiple Access Scheme

Waveform/Multiple Access Scheme

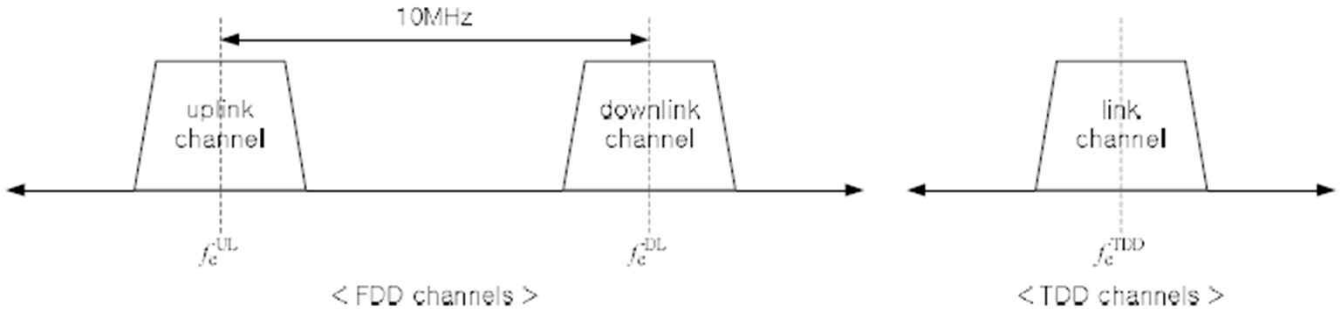
- Specify waveform/multiple Access Scheme for e-WSN
- e.g., FMT(Filtered Multi-Tone)



eWSN PHY – Numerology, Frame structure, Duplex (1)

Numerology

- DL/UL/SL: 25kHz SCS(sub-carrier spacing)
- Other SCS can be further studied (12.5kHz, 50kHz, 100kHz)



Example: FDD/TDD channels for eWSN

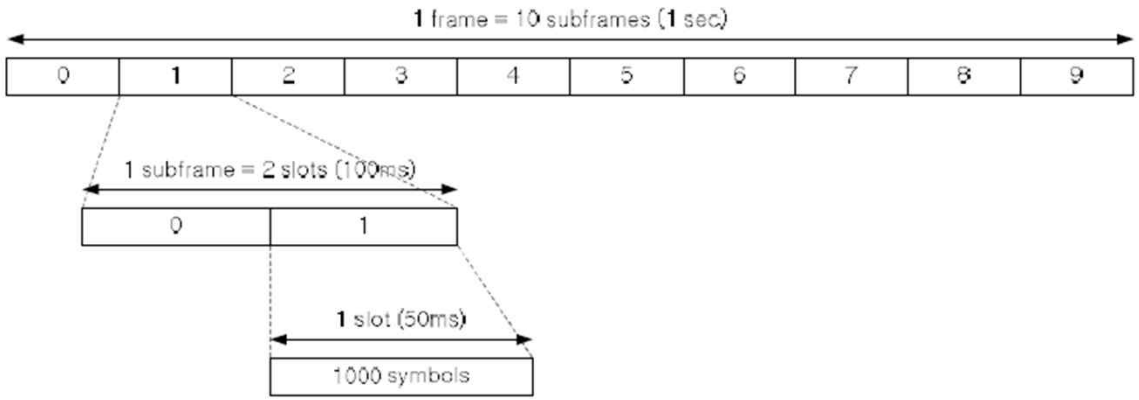
Duplex

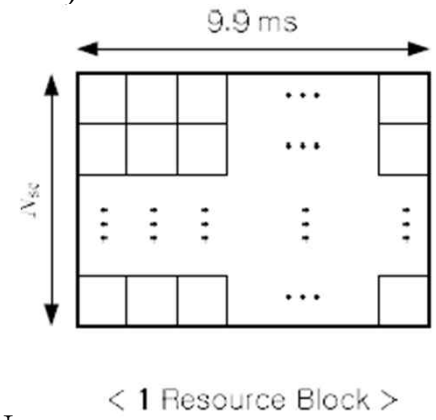
- (Cost Effective)Half duplex
- (Real Time)Full duplex

eWSN PHY – Numerology, Frame structure, Duplex (2)

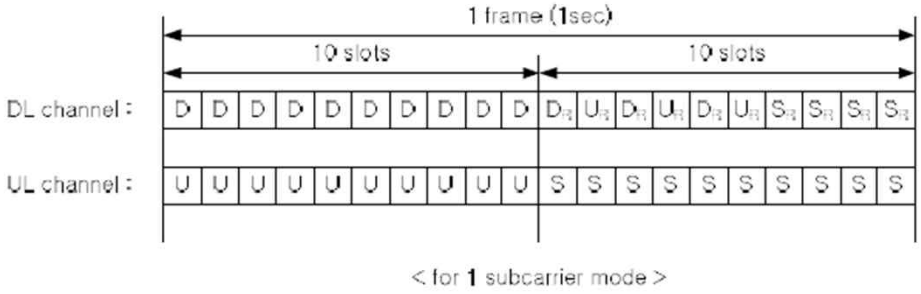
Frame Structure

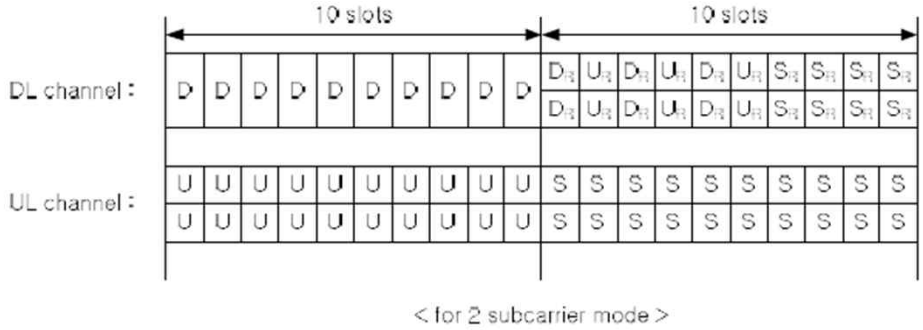
- Specify FDD/TDD frame structure with DL(downlink)/UL(uplink)/SL(sidelink)



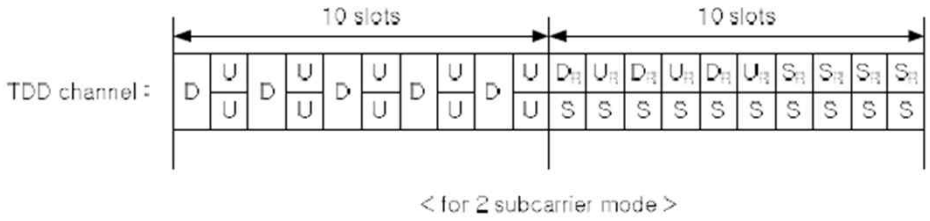


Example: General frame structure for eWSN





Example: FDD frame structure for eWSN

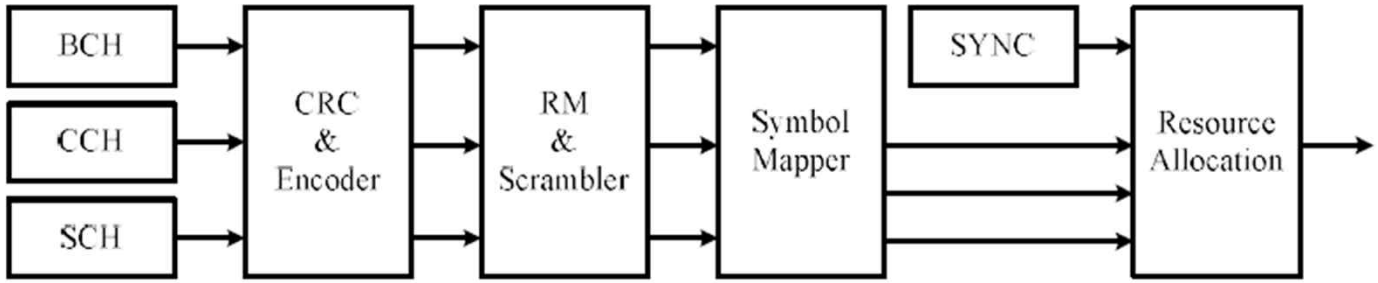


Example: TDD frame structure for eWSN

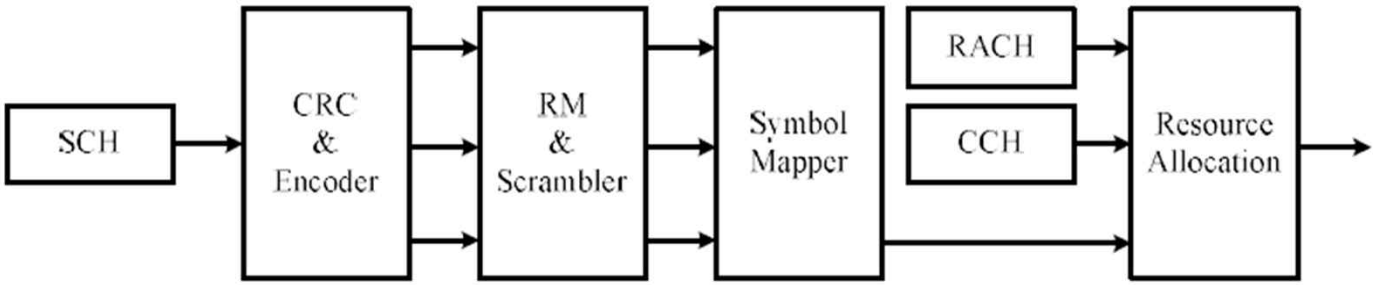
eWSN PHY – Tx/Rx structure

TX/Rx structure

- Specify general DL/UL channel processing
- Specify channel coding scheme for each physical channel
  e.g., Turbo code, convolution code
- Specify scrambling scheme for each physical channel
- Specify modulation scheme for each physical channel
  e.g., QPSK, 16-QAM, 64-QAM



Example: DL physical channel processing for eWSN

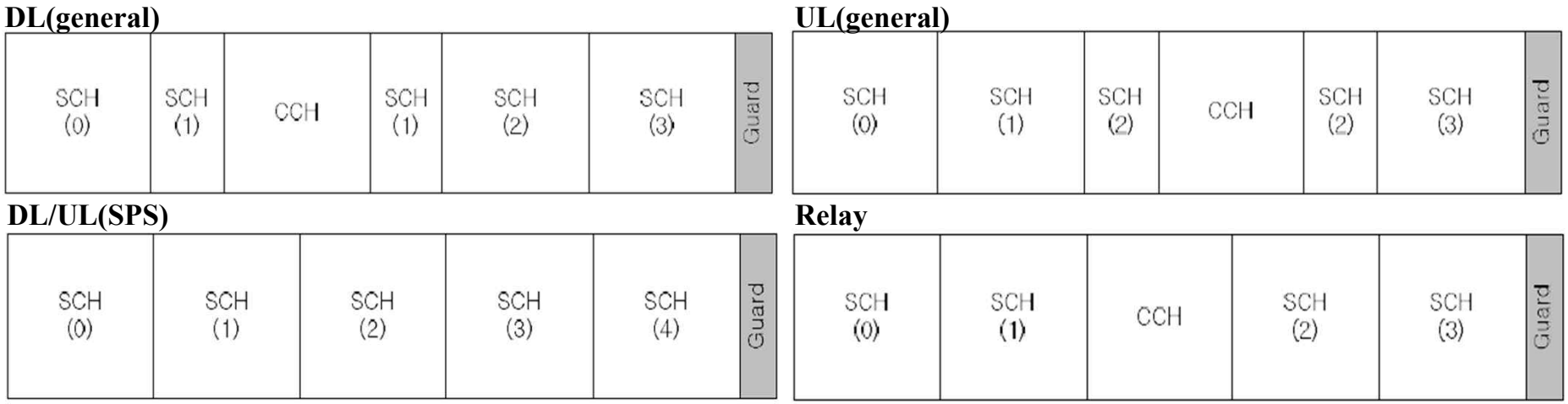


Example: UL physical channel processing for eWSN

eWSN PHY – Physical Channels/Signals (1)

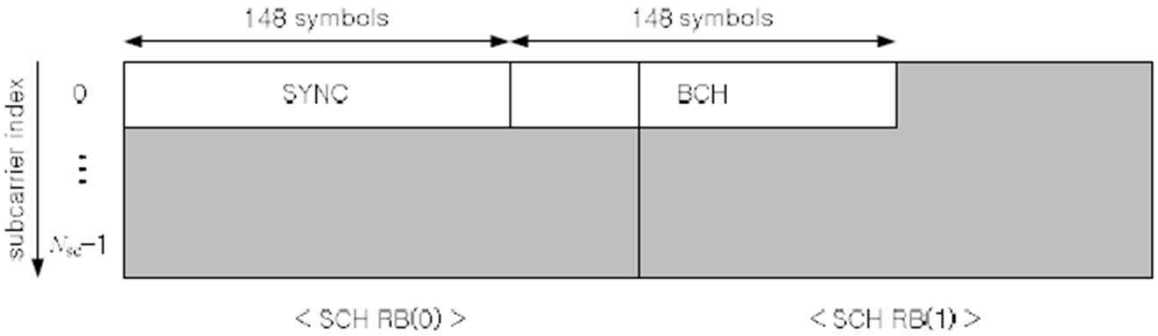
Physical Channels/Signals

- Specify DL channels/Signals
  e.g., Synchronization signal, BCH(broadcast channel), DCCH(Downlink Control Channel), DSCH(Downlink Shared Channel), DRS(Downlink Reference Signal)
- Specify UL channels/Signals
  e.g., RACH(Random Access Channel), UCCH(Uplink Control Channel for ACK/SR/CQI), USCH(Uplink Shared Channel), URS(Uplink Reference Signal)
- Specify SPS(semi-persistent scheduling) channels for DL/UL
- Specify Relay channels/Signals for SL (using DL and/or UL resources)
  e.g., R-SYNC, R-BCH, R-DCCH, R-DSCH, R-DRS, R-RACH, R-UCCH, R-USCH, R-URS, R-SPS

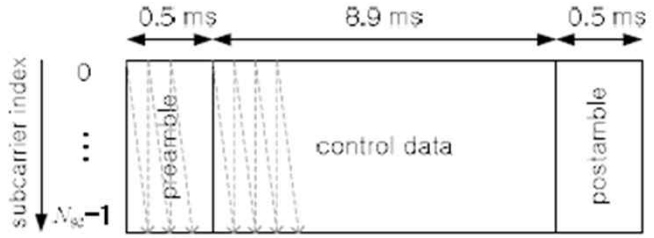


Example: slot structure for physical channels for eWSN

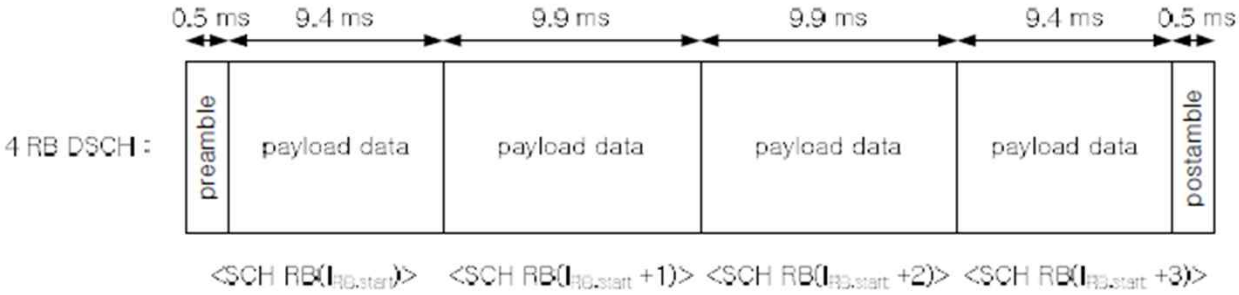
eWSN PHY – Physical Channels/Signals (2)



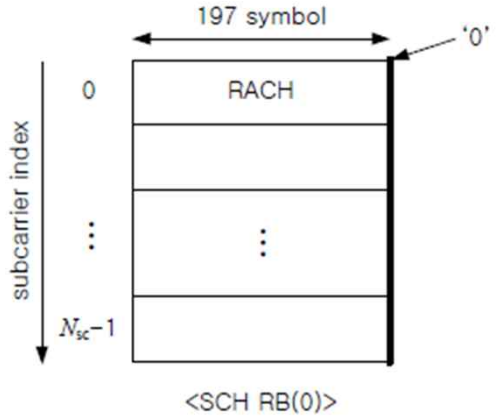
Example: Synchronization signal and BCH structure for eWSN



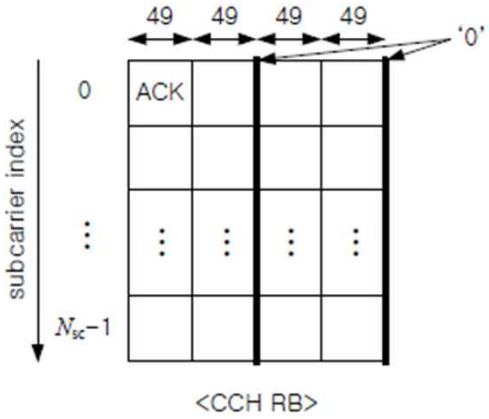
Example: DCCH structure for eWSN



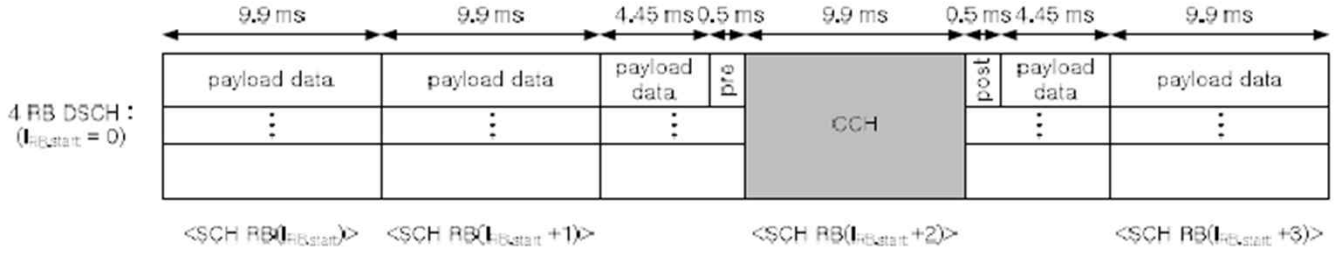
Example: DSCH structure for eWSN



Example: RACH structure for eWSN



Example: UCCH(ACK) structure for eWSN



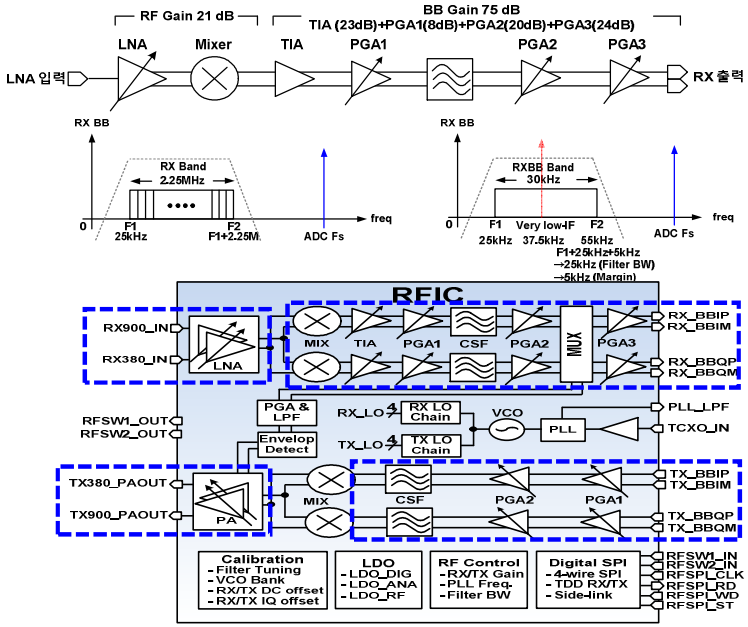
Example: USCH structure for eWSN

4. Performance

Transceiver implementation

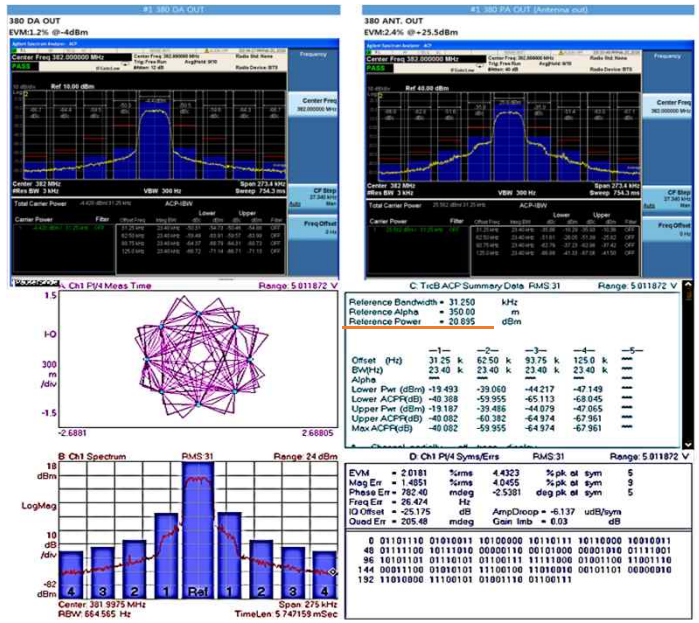
1 RFIC design

- Bandwidth : (380+917MHz) + (320+940MHz)
- Tx Power : 23dBm(w/o AMP), 30dBm(AMP)

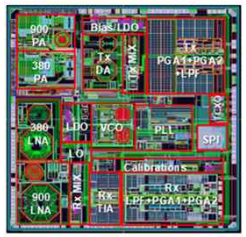


2 RFIC implementation and Test

- Size of RF IC DIE : 4mm * 4 mm
- Test for regulation in Korea



3 Baseband chip based on proposed standard

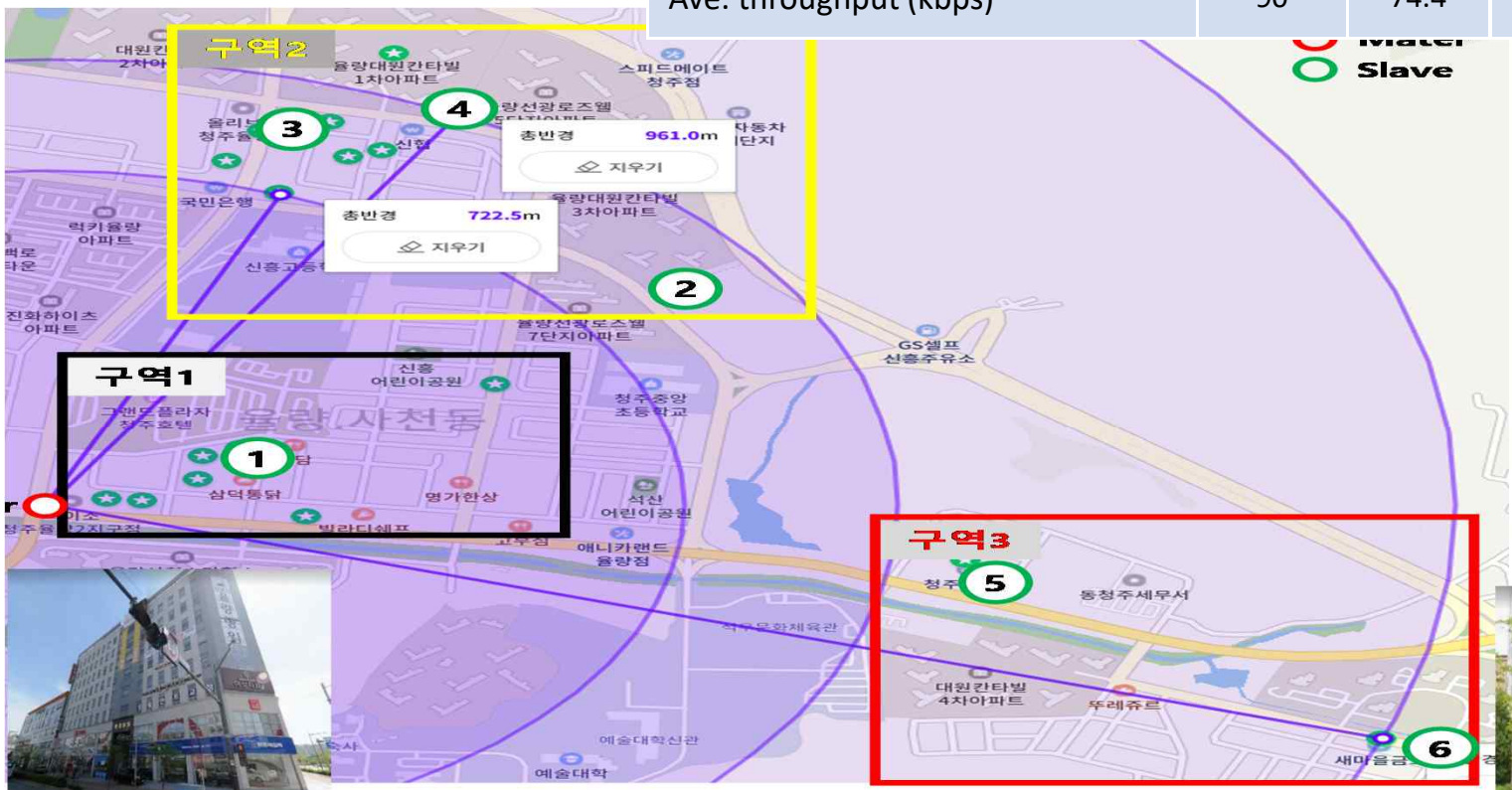


4. Performance

Field Test

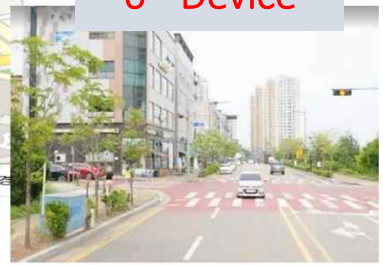
Device	#1	#2	#3	#4	#5	#6
Distance (m)	230	850	870	940	1090	1680
Reliability (%)	100					
Received power (dBm)	-79.72	-95.78	-98.46	-96.22	-98.12	-104.1
MCS	64QAM	16QAM	16QAM	16QAM	QPSK	QPSK
Ave. throughput (kbps)	90	74.4	60	66.4	44.5	34.5

4th Device



Gateway

6th Device



4. Conclusion – Standard Proposal

Standard Proposal

- The Smart Grid is important IoT service for energy system. It needs 10~100Kbps per node for throughput, 20ms for latency, and 99% reliability. However, there is no technology satisfies 100Kbps peak rate with bandwidth≤25kHz in current narrowband technology for industry licensed frequency band, regarding 3GPP MTC/NB-IoT, IEEE Wi-Sun and LoRa/SigFox.

- This standard is to define new radio access technology in field area network for Smart Grid by development of robust wireless sensor network based on licensed narrowband. It focuses enhanced PHY technology for new-smart utility using industry licensed frequency band with some 3GPP NB-IoT based schemes.

- This standard is proposed as a new PHY technology for Smart Grid. It includes a PHY channel design to satisfy 100Kbps per node, new waveform(FMT) on 12.5kHz/25kHz narrow bandwidth, frame structure for latency reduction, relay to remove coverage hole

4. Conclusion – Time Plan

- **This standard proposed a method of ~**

4Q of 2021	- Concept of is presented - Initiate New Proposal Voting of
2Q of 2022	- Working Draft circulated to experts
4Q of 2022	- Committee Draft ballot
4Q of 2023	- DIS submission
4Q of 2024	-Publication

Reference

[1] 3GPP RP-152284, “Revised Work Item: Narrowband IoT(NB-IoT)”, Huawei, HiSilicon

[2] 3GPP TS 36.211, “Evolved Universal Terrestrial Radio Access(E-UTRA); Physical channels and modulation”