Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [IEEE 802.4k System Proposal - ISWAN (Integrated Services Wide Area Networks)]

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Re: [802.15.4K final proposal call]

Abstract: [IEEE 802.4k System Proposal - ISWAN (Integrated Services Wide Area Networks)]

Purpose: [Presented to the IEEE802.15.4k LECIM task group for consideration]

IEEE 802.4k System Proposal
- ISWAN (Integrated Services Wide Area Networks)

- Shu Kato[1], Hirokazu Sawada[1], Lawrence Materum[1], Nobuhiko Shibagaki[2]]

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ISWAN Proposal

- Summary

1. Applications
2. Frequency band
3. Network topology
4. MAC
5. PHY
6. Major system parameters
7. PHY/MAC Consideration
8. Conclusion

Summary

- In order to realize more economical low energy sensor systems, Integrated Services Wide Area Networks (ISWAN) has been proposed. ISWAN intends to provide multiple services ranging from low cost wide area sensor/monitoring, to anti-disaster & disaster-relief systems by one physical network.
- The proposed system adopts DSSS with strong FEC to mitigate high path loss / wider coverage, high and unknown interferences in the unlicensed bands and to realize high reliable sensor data transmission with TDMA –TDD as access methodology (with an option of non-beacon transmission).
- To enhance reliability further, a Double layer topology with multiple frequency bands has been proposed.
- To realize lower power consumption, a dynamic network configuration, “Non-beacon and TDMA-TDD with beacon” system has been proposed as an alternative MAC.

Applications

- Higher layer **integrated Services Wide Area Network** (**ISWAN**) as a part of LECIM: Sharing one physical system by many different applications supporter by wider coverage and high reliability
- Key characteristics required:
  - i. Low energy consumption: **battery operation**
  - **nodes for 10 $^{+}$ years**
  - ii. Long transmission range: **targeting for 20 km, 120 dB path loss**
  - iii. Co-existence in unlicensed bands: **up to 8 orthogonal networks**
  - iv. **Integrated services by one physical system**
  - **v. High reliability to serve all required nodes**
  - **vi. Meeting required latency for each service**

- Leading to a high reliable, high efficient and cost effective wide area network: **ISWAN**

Successful Deployment of LECIM depends on Cost and Reliability – including Disaster Relief Networks

•The cost will be reduced by sharing the one physical system by multiple applications /services

•The reliability will be enhanced by higher link margin and network topology

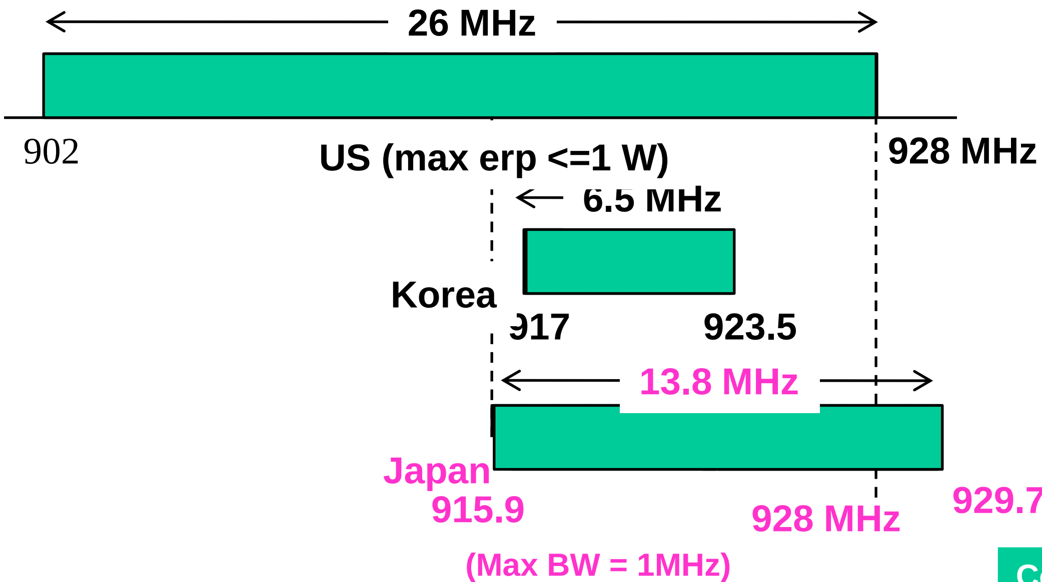
•**Non-emergency Application examples**: **Cost needs to be lower for more use, better deployment**

1. Infrastructure: Power transmission/distributions, Gas distribution, Oil pipeline, bridge, dam, road, …
2. Building monitoring,
3. Agriculture：water temperature, humidity, PH, water depth….
4. Fishery：Sea water temperature, toxic,
5. Environment：Rainfall, Temperature, Wild animal monitoring,
6. Health: Aged people, Children tracking/monitoring
7. Others

•**Emergency applications**

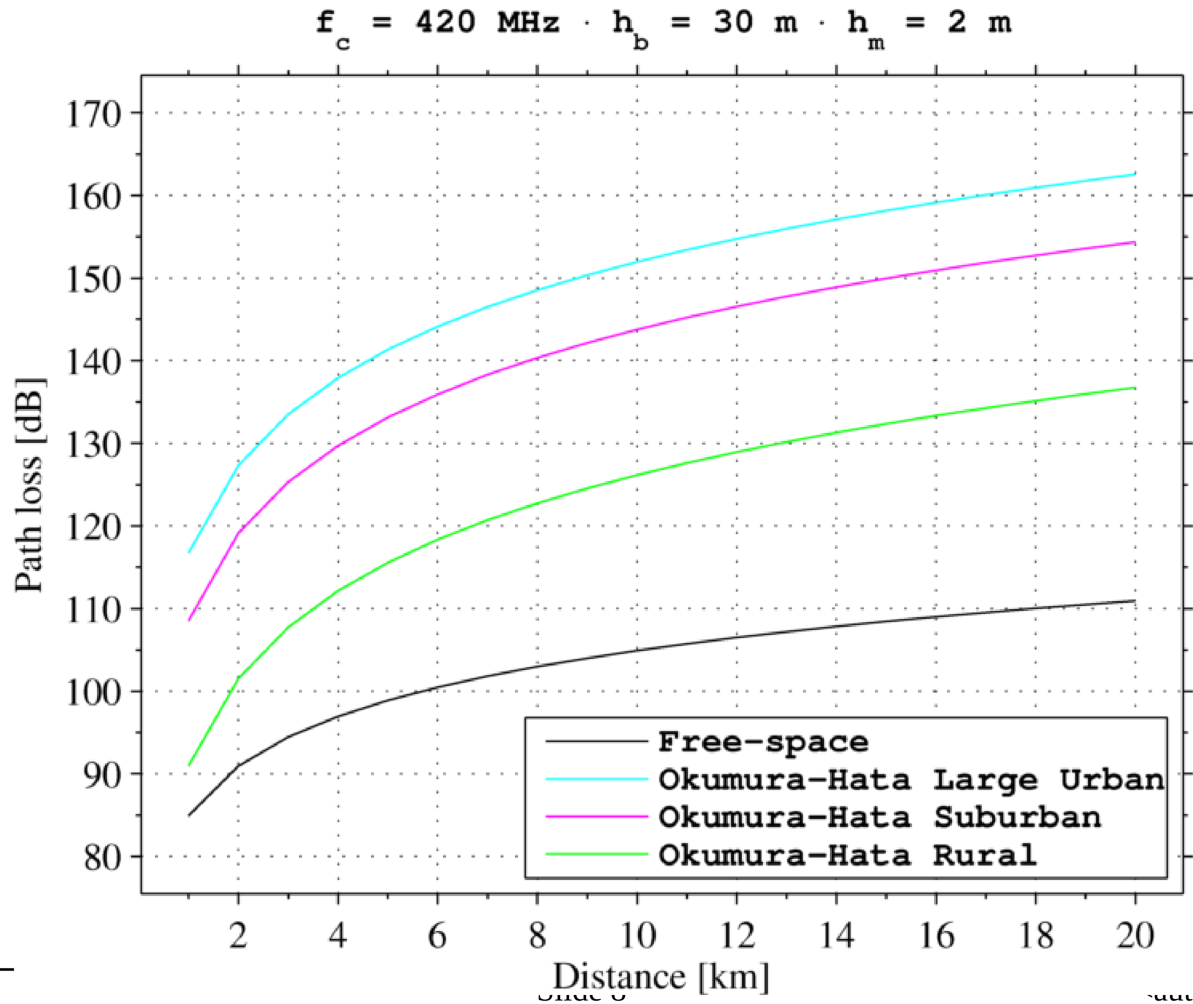
1. Anti-disaster: such as Detecting Tsunami in advance
2. Disaster relief

A New 900 MHz Spectrum Allocation in Japan : 13.8 MHz

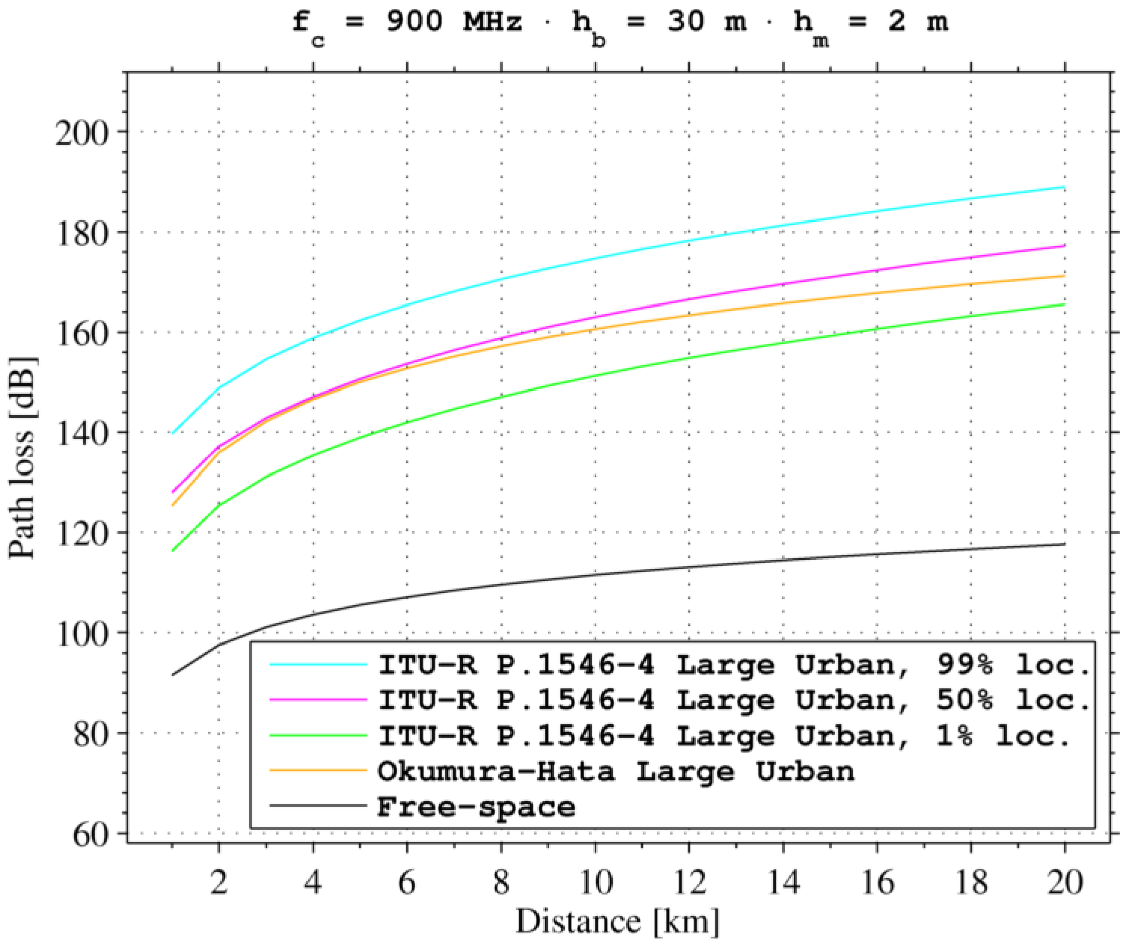


Country	Tx power regulations
USA	Max e.r.p. <= 1 W
Korea	3 mW or 10 mW (920.6~923.5MHz and six 200 KHz channels below 920.6 MHz)
Japan	1mW , 20 mW or 250 mW (915.9~929.7MHz) Max BW = 1 MHz

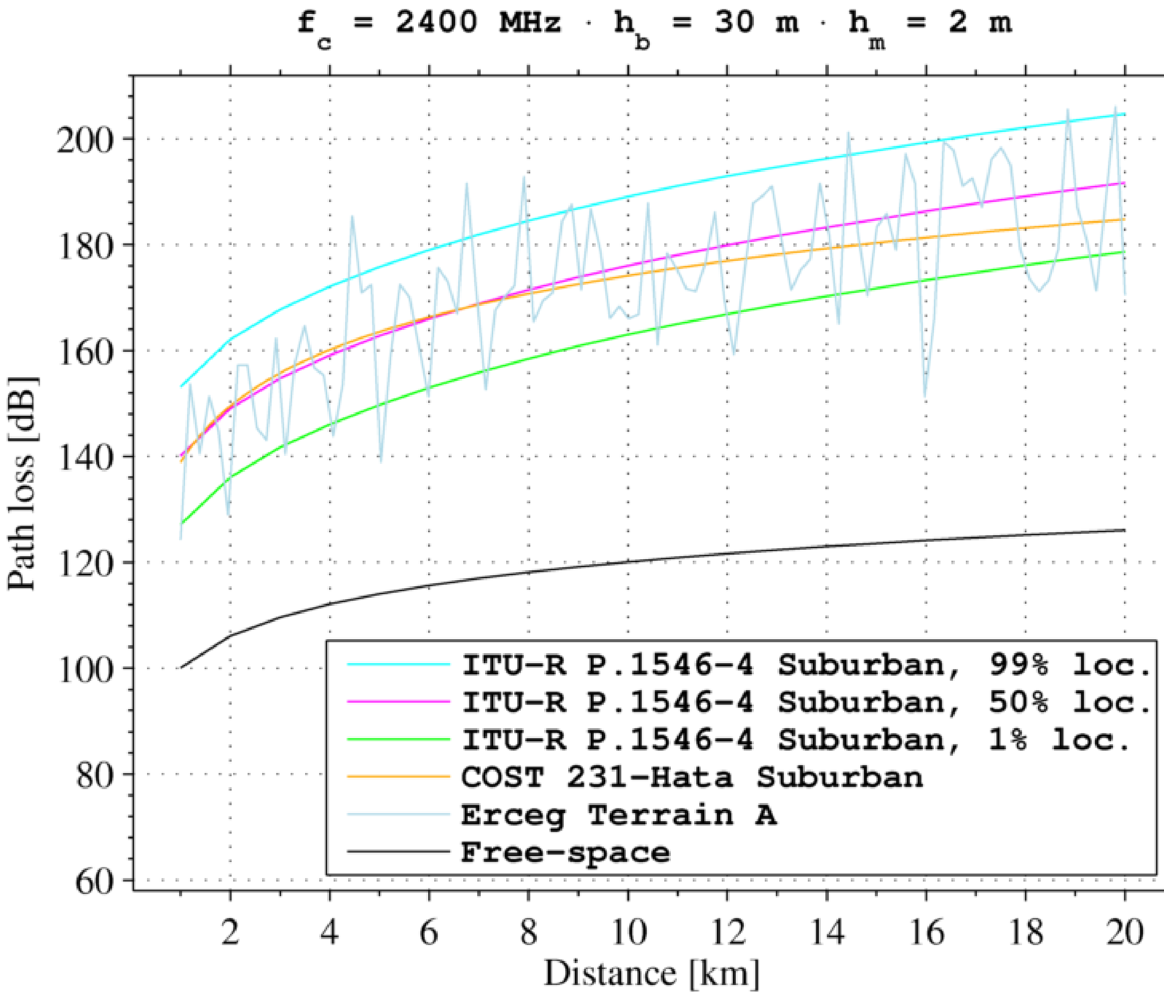
Path Loss Characteristics at 420 MHz (Okumura-Hata Model: assumed): 25 dB Lower than 900 MHz@10 k m



Path Loss Characteristics at 900 MHz (Okumura-Hata Model: assumed)



Path Loss Characteristics at 2.4 GHz (Okumura-Hata Model: assumed)



Spectrum Candidates and TX Power and Antenna Gain Regulations for ISWAN in Japan

	TX power	Antenna gain	Channel bandwidth	Antenna Tx power(dBm)	Relative path loss (dB)	Use case
429.8125 - 429.925MHz	10mW	~ 2.14 dBi	8.5kHz	12 dBm	**0**	Telemeter, Tele-control, Data transmission
920.5 - 923.5MHz	250mW	3dBi	200kHz×n (n=1 – 5)	30 dBm	**- 6.6**	Sensor Networks, Smart Meters (Middle Power)
920.5 – 928.1MHz	20mW	3dBi	200kHz×n (n=1 – 5)	16 dBm		Sensor Networks, Smart Meters Low Power(Basic)
920.5 - 923.5MHz	20mW	3dBi	200kHz×n (n=1 – 5)			Tele-metering, Tele-control (Low Power (Extended))
915.9 - 928.1MHz	1mW	3dBi	200kHz×n (n=1 – 5)			Active RFID (Ultra Low Power (Basic))
928.1 - 929.7MHz	1mW	3dBi	200kHz×n (n=1 – 5)			Remote control (Ultra Low Power (Extended))
2400MHz ~2483.5MHz	10mW/MHz	~ 12.14 dBi	26MHz 38MHz(OFDM)	36.2 dBm (/26 MHz)	**- 15**	(WLAN)

Frequency and Dual-band Operation for Higher Reliability

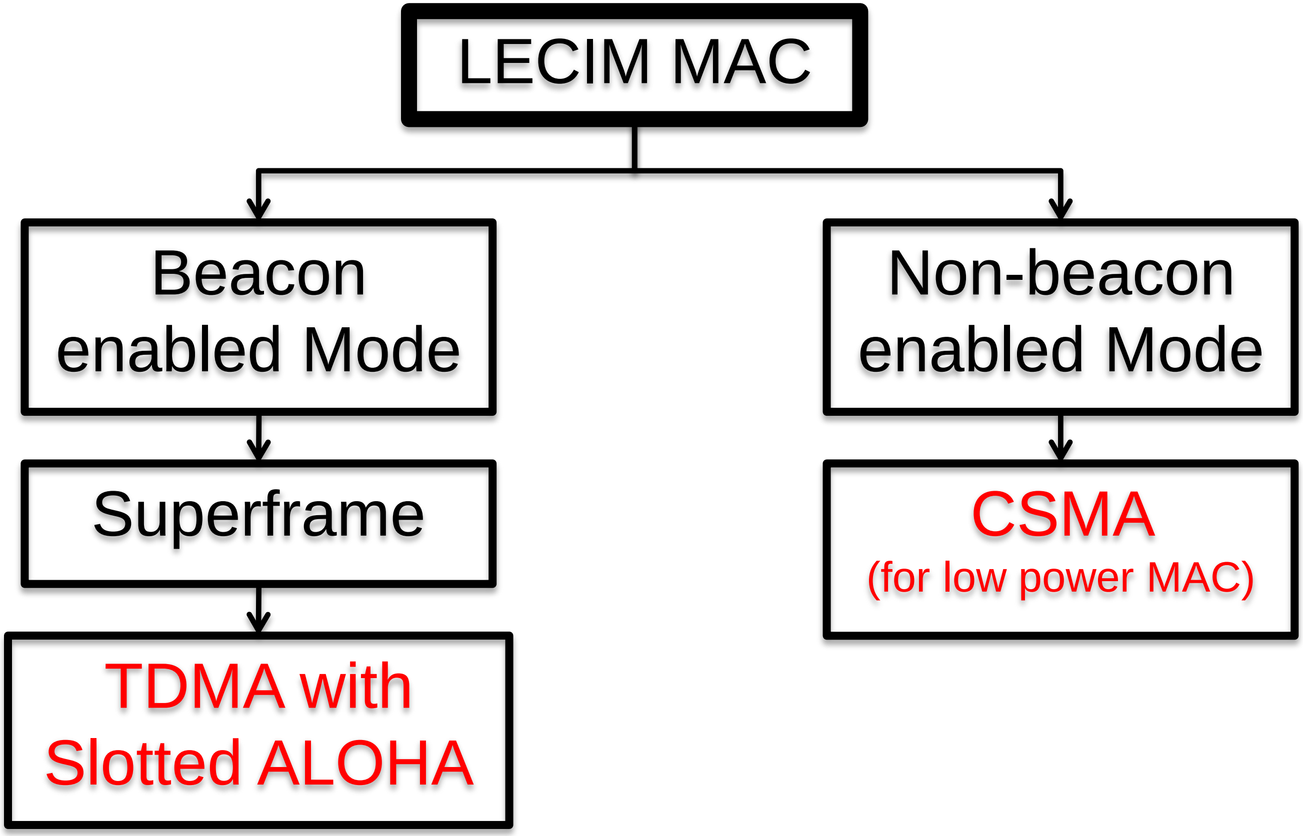
1. **Unlicensed band** for better global / local promotion

- - 2.4 GHz,
- - 920 MHz,
- - 420MHz (in Japan)
- 2. **Dual-band nodes** / AP for better connectivity
- 2.4 GHz / 423 MHz, 920 MHz / 423 MHz
- 3. **Bandwidth**
- i. 2.4 GHz / 900 MHz: 1 MHz with 1 MHz guard band
- ii. 423 MHz (in Japan): 8.5 kHz/Ch
- (May lead to a new MAC development necessity)

Topology: Double layer Network

1. Two layer topology composed of STAR like networks (Top layer) and Bottom layer
2. Star like network with one AP and many nodes (devices) for higher capacity and low system & operation cost
3. Bottom layer network with higher reliable connections to Top layer nodes with low capacity as an extension for specific applications / environments

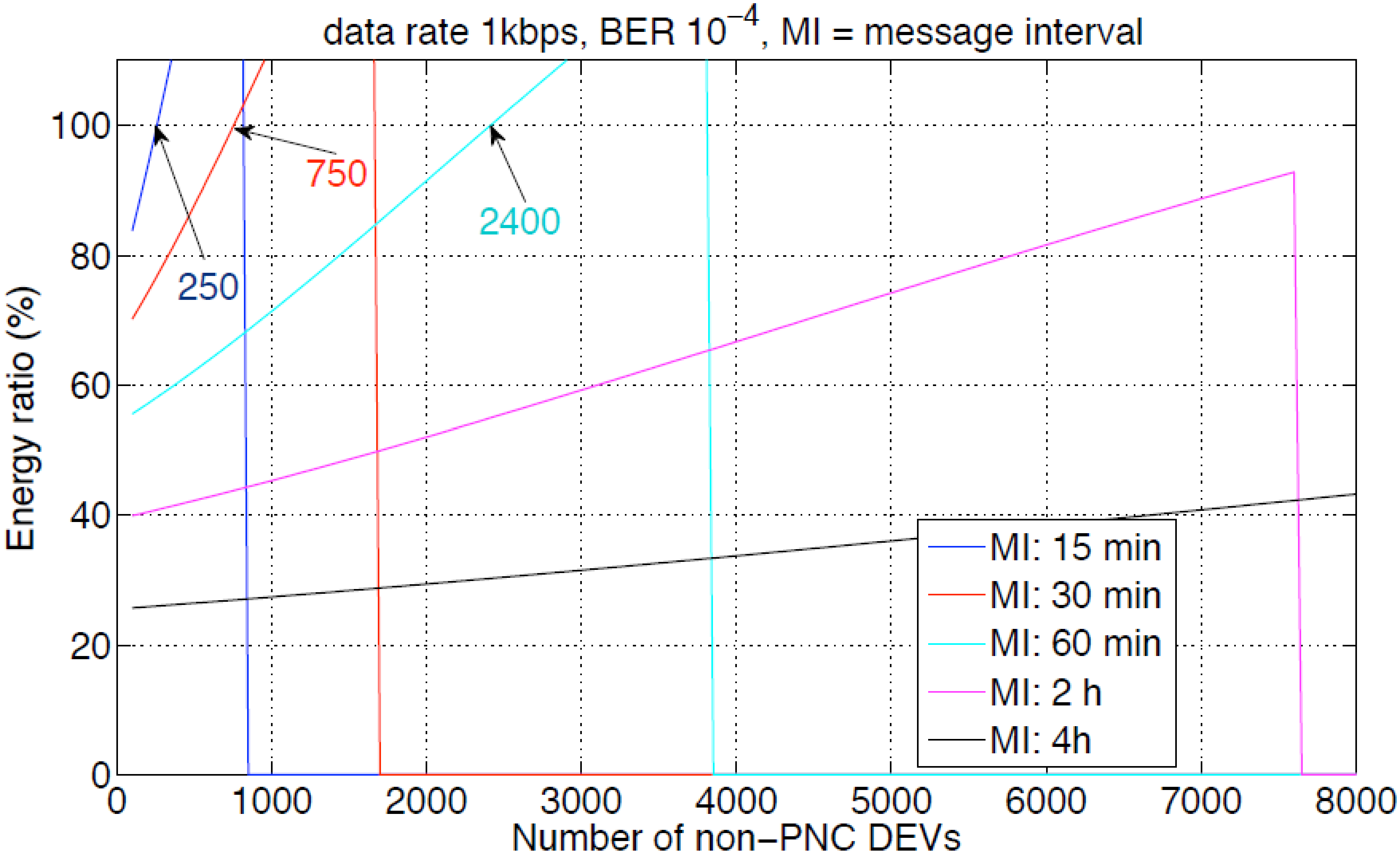
Proposed MAC Modes: Dual mode MAC - CSMA mode for small number of terminals



- CCA - even though not very effective – comes with little additional cost and it is used in non-beacon enabled mode for generality.

Energy Ratio Example: non-beacon enabled over slotted TDM

Non-beacon mode is quite energy efficient with low duty ratio devices



Low Power and High Reliability

- **Low power MAC:** two dynamic mode change – Non-beacon and TDMA-TDD
- **Double layer network topology** for higher reliability
- **Fragmentation :** mandatory for reliable transmission in interference environment /unlicensed bands - how to implement fragmentation will be depending on TG4K discussion (Ref.: Rolf)

PHY

I. Modulation: Constant / quasi-constant envelope modulation – GMSK / XPSK, OQPSK, Pie/2 DBPSK

II. FEC: Convolutional encoding – Viterbi decoding (R=1/2, K=7)]

    Double SD Maximum Likelihood Decoding for 5.5 dB coding gain

I. TDMA/TDD (optionally non-beacon systems)

II. DSSS for uplink and down link to mitigate high path loss and interference: spreading factor ranging from 1 – 10,000

III. Bit rate: Adaptive bit rates ranging from 100 bps to 40 kbps by changing spreading factor and modem rates

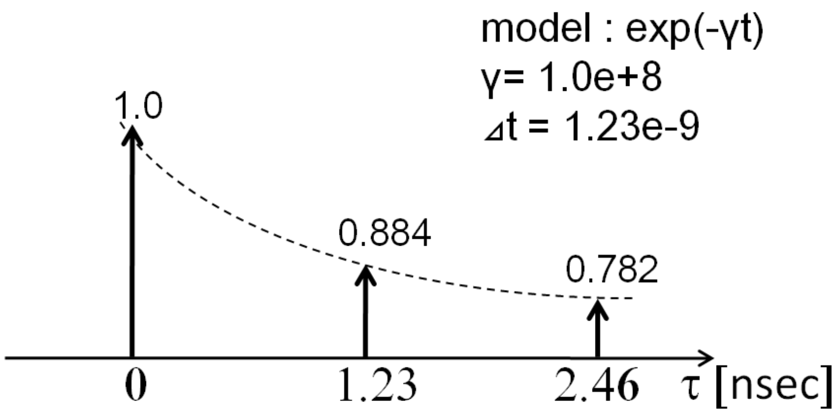
IV. Software defined modem for both Top layer and Bottom layer communications

V. Hi PAE PA by “constant envelope” modulations: low power consumption

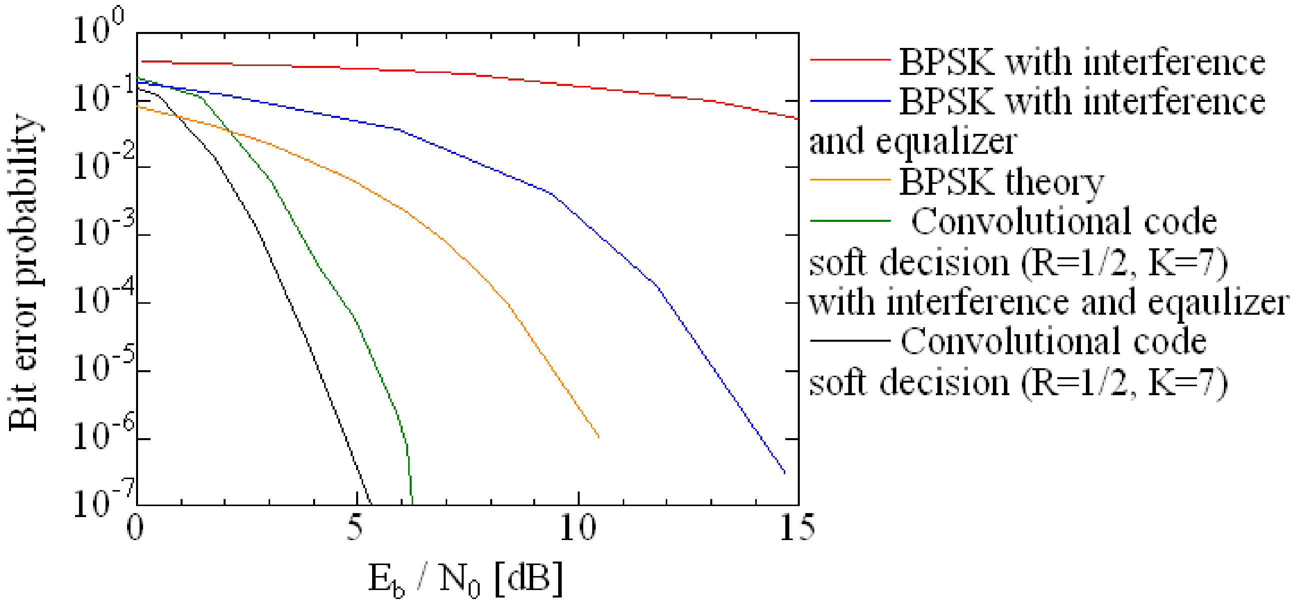
VI. Beam forming antenna for higher link margin and higher reliability – beam direction adjustment at installation based on TG3C Specification / technology

Convolutional Encoding and Viterbi Decoding Performance Higher Coding Gain in Interference than AWGN Environments

Assumed channel model:
Two path exponential decay



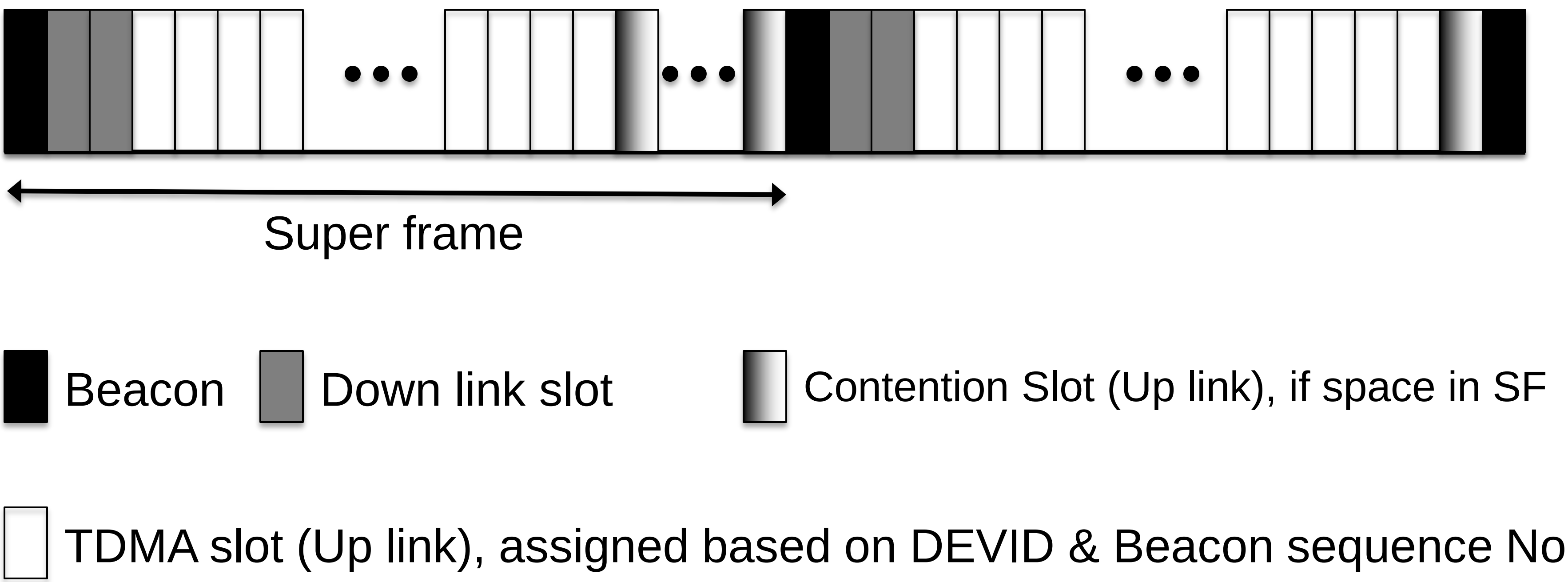
More than 7 dB Coding gain at Pe=1 x 10-4



Major system parameters

1. Channel bandwidth:
    i. 1 MHz for 920 MHz and 2.4 GHz
    ii. 8.5 kHz for 420 MHz
2. Bit rates:
    i. Category 1 – up to 40 kbps/ 1 MHz
    ii. Category 2 – up to 9.6 kbps/ 8.5kHz for Bottom layer
3. Spreading factor: 1 – 10,000 for category 1
4. Antenna gain: up to regulations limit
    2.4 GHz: 10-12 dBi with beam forming capability
    900 MHz, 420 MHz: 2-3 dBI
5. Tx output power: up to regulations limit (Limits in Japan shown below)
    2.4 GHz:10 dBm
    900 MHz: 10/24 dBm
    420 MHz: 10 dBm
6. MCS
    "Constant envelope modulation" for power efficiency: GMSK, XPSK, (OQPSK, pie/2 DBPSK)
    FEC: Convolutional encoding and Viterbi decoding (R=1/2, K=7)

Super frame format for TDMA-TDD



- Slot length dynamically adjusted

(Length based on ACKed data transaction with lowest bit rate)

ISWAN Link Budget Example

Channel model	Hata (large urban)	Hata (large urban)	Erceg (Flat)
Channel Model Parameters			
Frequency (MHz)	420	920	2400
Collector Antenna Height (m)	10	10	10
Endpoint Antenna Height (m)	2	2	2
Distance (km)	6.5	8	10
Channel Band Width(KHz)	8.5	1000	1000
Downlink Path Loss Calculation			
Collector Tx Power (dBm)	10	24	10
Collector Tx Antenna Gain (dBi)	2	3	12
Path Loss (dB)	−154.5	−166.9	−174.4
Shadowing Margin (dB)	0	0	0
Penetration Loss (dB)	−10	0	0
Endpoint Rx Antenna Gain (dBi)	2	2	2
Endpoint Interference (dB)	1	1	1
Rx Power at Endpoint (dBm)	**−149.5**	**−136.9**	**−149.4**
Spread gain (dB)	33	33	33
FEC gain (dB)	5.5	5.5	5.5
Reciever sencitivity (dBm)	**−111.0**	**−98.4**	**−110.9**
Uplink Path Loss Calculation			
Endpoint Tx Power (dBm)	10	10	10
Endpoint Tx Antenna Gain (dBi)	2	3	12
Penetration Loss (dB)	−10	0	0
Path Loss (dB)	−154.5	−166.9	−174.4
Shadowing Margin (dB)	0	0	0
Collector Rx Antenna Gain (dBi)	2	2	2
Collector Interference (dB)	2	2	2
Rx Power at Collector (dBm)	**−148.5**	**−149.9**	**−148.4**
Spread gain (dB)	33	33	33
FEC gain (dB)	5.5	5.5	5.5
Reciever sencitivity (dBm)	**−110.0**	**−111.4**	**−109.9**

PHY/MAC Consideration

1. To mitigate high path loss of 120 dB and high interference in unlicensed bands, DSSS is the most efficient way as proposed by On-Ramp as well and we promote this approach basically with following major items to be clarified
2. Major items need to be clarified

   i. Synchronization of direct sequence spread code in very low C/N environments, 40 dB lower than conventional SC transmission,

   (We propose to use Golay sequence with a length of 512)

   ii. Preamble design (of the packet) fro robust communications,

   (We propose to use Gold code or M-sequence with a length of 32 – 48)

   iii. Modulation schemes: constant envelope, quasi constant envelope**, (We propose to use constant envelope or quasi-constant envelope modulation schemes)**

   iv. TDMA –TDD frame structure for multiple services

   v. PSDU FCS: 16 bit FCS will be good enough

   vi. Device wake up process and system management

   vii. Network coordination/synchronization

   Viii. Necessity of interleaver?

Conclusion

ISWAN for High Reliable and Low Power Monitoring Systems

- In order to realize more economical low energy sensor systems, Integrated Services Wide Area Networks (ISWAN) has been proposed. ISWAN intends to provide multiple services ranging from low cost wide area sensor/monitoring, to anti-disaster & disaster-relief systems by one physical network.
- The proposed system adopts DSSS with strong FEC to mitigate high path loss / wider coverage, high and unknown interferences in the unlicensed bands and to realize high reliable sensor data transmission with TDMA –TDD as access methodology (with an option of non-beacon transmission).
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