Document RSG1SG5-IoT-16/1-E
19 November 2016
English only

ITU Workshop on
Spectrum Management for
Internet of Things Deployment
(Geneva, 22 November 2016)

IoT deployment in SRD networks

Dr. Haim Mazar (Madjar)
ATDI Spectrum & Engineering

IoT most relevant activities to WP 5A

1. RLAN (Wi-Fi; IEEE 802.11) connecting IoT
2. Wide-area sensor and/or actuator network (WASN) systems supporting M2M:
   Q. 250-1/5; Rec. M.2002; Rep. M.2224
3. Characteristics and examples:
   1) Ultra-narrowband UNB, Narrowband, Wideband (broadband)
   2) Long range (LoRaWAN, SigFox, Weightness, Ingenu …)
   3) Short range (BTLE, IEEE 802.11ah, IEEE 802.15.4, DECT, ZigBee, Z-wave …)

The full presentation appears at the ITU WEB; I won't present all slides

SRDs and IOT

'The Internet changed our lives, and the Internet of Things will change us again' Jason Hiner

1. Machine to Machine (M2M) interconnect via licensed mobile systems (such as cellular and PMR) or via unlicensed infrastructure of Short Range Devices (SRDs)
2. RLAN (Wi-Fi) and other SRDs (such as Bluetooth, Zigbee, Wi-SUN, Z-WAVE) may connect IoT to wireless networking
3. Do we need a specific or additional RF band dedicated to IoT at the RF SRD RF bands?

Frequency Bands for SRDs

Global — 9-148.5 kHz; 3,155-3,400 kHz
Only in Europe — 9 kHz- 47 MHz (specific SRDs)
Only in Americas — 7,400-8,800 kHz

ISM bands

6,780 kHz; 13,560 kHz
27,120 kHz; 40.68 MHz
433.92 MHz
915 MHz
2,450 MHz; 5,800 MHz
24.125 GHz; 61.25 GHz
122.5 GHz; 245 GHz

138.20-138.45 MHz
169.4-216 MHz
312-315MHz (non Europe)
402-405 MHz medical devices
470-489 MHz (normally individually licensed)
823-832 MHz and 1,785-1,805 MHz
862-875 MHz in some Asian counties
862-876MHz Non-Specific SRDs
915-921 MHz (in some countries)
5,150-5,350 & 5,470-5,725 MHz
57-64GHz, 76-77GHz, 77-81GHz

non-ISM candidate bands for SRDs

Fig 3.1 ; Mazar's Wiley book 2016
https://www.amazon.com/Radio-Spectrum-Management-Regulations-Techniques/dp/1118511794

To add specific RF to IoT at SRD bands?

1. Resolution 958 (WRC-15), Annex item 3 and WRC-19 Agenda Item 9.1 (issue 9.1.8) ‘Studies on the technical and operational aspects of radio networks and systems, as well as **spectrum needed**, including possible harmonized use of spectrum to support the implementation of **narrowband and broadband machine-type communication infrastructures**‘

2. In addition to mobile systems (such as GSM), without prejudging WRC-19 results, the **present SRDs RF bands, shown at previous slide, <u>may</u> provide to IoT the necessary coverage and capacity** for narrow and wideband, in narrow and wide area

Wi-Fi: greatest triumph after GSM

Wi-Fi, RLAN, WLAN, U-NII (Unlicensed-National Information Infrastructure) operating in 5.15-5.35 GHz and 5.470-5.85 GHz)

Unrelated to IoT, for me personally, **when abroad**, connected to RLAN is **more important** than cellular connection, to offer **free** internet connection and audio/ **video** calls

Wi-Fi Global: derived from Rec M.1450

Characteristics	IEEE Std 802.11-2012 (Clause 17, commonly known as **802.11b**)	IEEE Std 802.11-2012 (Clause 18, commonly known as **802.11a**)	IEEE Std 802.11-2012 (Clause 19, commonly known as **802.11g**)	IEEE Std 802.11-2012 (Clause 18, Annex D and Annex E, commonly known as **802.11j**)	IEEE Std 802.11-2012 (Clause 20, commonly known as **802.11n**)	IEEE P802.11ac	IEEE Std **802.11ad**-2012	ETSI **EN 300 328**	ETSI **EN 301 893**	ARIB HiSWANa,	ETSI EN **302 567**
Frequency band	**2 400-2 483**	**5 150-5 250 MHz 5 250-5 350 MHz(4) 5 470-5 725 MHz 5 725-5 825 MHz**	**2 400-2 483.5 MHz**	**4 940-4 990 MHz 5 030-5 091 MHz 5 150-5 250 MHz 5 250-5 350 MHz 5 470-5 725 MHz 5 725-5 825 MHz**	**2 400-2 483,5 MHz 5 150-5 250 MHz 5 250-5 350 MHz 5 470-5 725 MHz 5 725-5 825 MHz**	**5 150-5 250 MHz 5 250-5 350 MHz 5 470-5 725 MHz 5 725-5 825 MHz**	**57-66 GHz**	**2 400-2 483.5 MHz**	**5 150-5 350 and 5 470-5 725 MHz**	**4 900 to 5 000 MHz 5 150 to 5 250 MHz**	**57-66 GHz**
Interference mitigation	LBT	LBT/DFS/TPC	LBT	LBT	LBT/DFS/TPC	LBT/DFS/TPC	LBT	DAA/LBT, DAA/non-LBT, MU	LBT/DFS/TPC	LBT	
Channel indexing	**5 MHz**				**5 MHz in 2.4 GHz 20 MHz in 5 GHz**	**20 MHz**	**2 160 MHz**		**20 MHz**	**20 MHz channel spacing 4 channels in 100 MHz**	

Major 802.11 (Wi-Fi) Standards

	802.11a	802.11b	802.11g	802.11n	802.11ad^	802.11ac*	802.11af**
Date of standard approval (release)	Sept. 1999	Sept. 1999	June 2003	Oct. 2009	Dec. 2012	Dec. 2013	February 2014
Maximum data rate (Mbps)	54	11	54	< 600	<7 Gbps		< 600***
Modulation	OFDM	CCK or DSSS	CCK, DSSS, or OFDM		SC and OFDM	OFDM	
RF Band (GHz)	5	2.4		2.4 or 5	60	5	TV bands below 1 GHz
Number of spatial streams	1			1 to 4	5 to 8	1,2,3,4 or 8	up to four streams
Channel width (MHz) nominal	20			20 or 40	80 or 160	20, 40, 80, 160	8 in Europe; 6 in N. America

WLAN: IEEE 802.11 Network bearer standards

Source: also Radio-Electronics.com

^ known also as µwave Wi-Fi; brand name WiGig operating in the 2.4, 5 and 60 GHz bands

* known also as Gigabit Wi-Fi, 5G Wi-Fi and 5G very high throughput (VHT)

** known also as White-Fi and Super Wi-Fi

*** max data rate is 426.7 Mbit/s in 6 & 7 MHz channels, & 568.9 Mbit/s for 8 MHz channels

WASN

1. Wide-area sensor and/or actuator network (WASN) systems supporting M2M

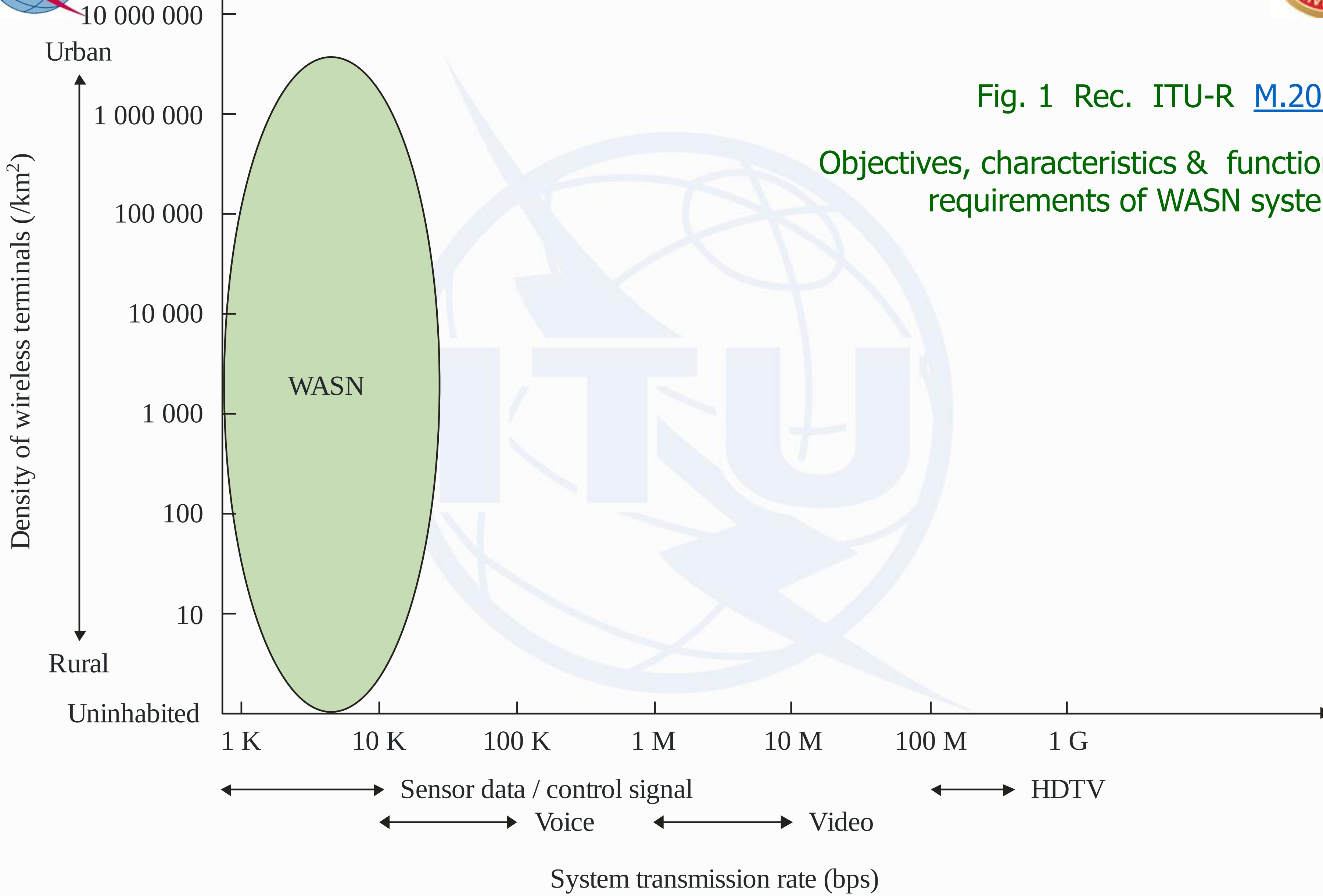
2. Mobile wireless access system is a large cell-based public network that can provide telecommunications to various objects including M2M services with wide area coverage

3. Large cell-based wireless access system with cell radius of about several to 10 km supports rural as well as urban areas

sensors or actuators: transmission rate & density supported by WASN systems

Fig. 1 Rec. ITU-R [M.2002]

Objectives, characteristics & functional requirements of WASN systems



M.2002-01

Main system parameters of VHF-band WASN

Report ITU-R M.2224

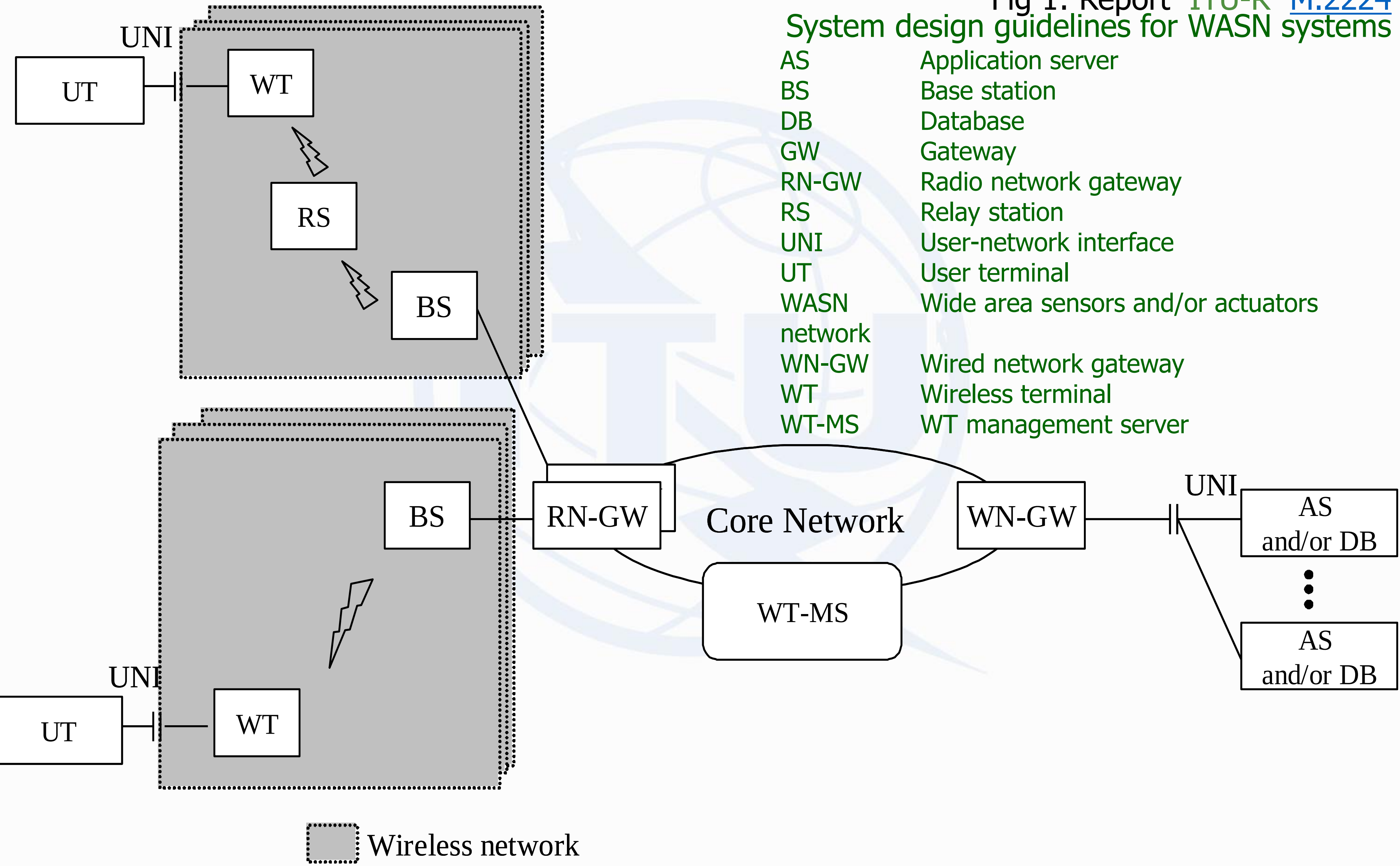
Parameters	Values	Notes
RF	Higher portion of VHF bands	280 MHz was licensed in Japan for experimental purposes only.
Modulation rate	Downlink: 9 600 baud Uplink: 9 600 baud	Modulation rate of 9 600 baud is considered the basic design of the system.
(option)	Uplink: 4 800, 2 400, 1 200, 600 baud	The uplink modulation rate is switched from 9 600 to 4 800, 2 400, 1 200 and 600 baud in order to increase link margins in metropolitan areas.
Transmission power	WT: 10 dBm BS: up to 36 dBm	The transmission power of WTs is defined as 10 dBm, assuming a low-power data communication system. BS transmission power is set to up to 36 dBm considering the man-made noise at WTs or the link margins in downlink.
(option)	WT: up to 30 dBm	The transmission power of WTs can be increased to increase link margins in metropolitan areas. The transmission power of WTs and BS can be adjusted for radio link design according to supported area or applications.
Multiple access method	TDMA	To accommodate a large number of WTs, TDMA is applied as the multiple access method. TDMA allows BS to flexibly control or assign bandwidth via a centralized control.
Duplexing method	TDD	TDD is applied as the duplexing method because two-way single-band transmission and open-loop transmission power control are available.
Modulation method	Downlink: π/2-shift; BPSK (signal); π/4-shift QPSK (data); Uplink:π/4-shift QPSK	For control signal transmission in downlink, π/2-shift BPSK is applied for robust operation of the system. For data transmission, π/4-shift QPSK is applied as the modulation method due to its spectral efficiency.
(option)	Downlink: 16QAM (data)	In addition to the parameters of the basic type, 16QAM is defined as an option for network management by multi-cast signal control in downlink.
Detection method	Downlink:Differential detection; Uplink: Coherent detection	On the WT side, differential detection is applied as a signal detection method, where frequency offset diversity can be applied. On the BS side, coherent detection is applied.
Forward error correction and interleaving	Convolutional coding and Viterbi decoding	To avoid transmission quality deterioration caused by fading and to improve the communication range, forward error correction is applied using convolutional coding and Viterbi decoding. In addition, bit interleaving on the temporal axis is applied to avoid burst errors caused by fading.
Tx power control (TPC)	Open-loop TPC	In uplink transmission, a simple open-loop TPC is applied to ensure a large reception dynamic range and to avoid the distance problem of the WTs in adjacent RF channels
Diversity method	Space and site diversity Uplink: MRC Downlink: RF offset	The system assumes that each WT has a single antenna and that an BS has multiple antennas. Thus, the diversity techniques of a multi-to-single antenna configuration in the downlink and a single-to-multi antenna one in the uplink are applied. In addition, space and site diversity techniques are combined to improve the diversity effect

WASN, Network configuration

Fig 1: Report ITU-R M.2224

System design guidelines for WASN systems

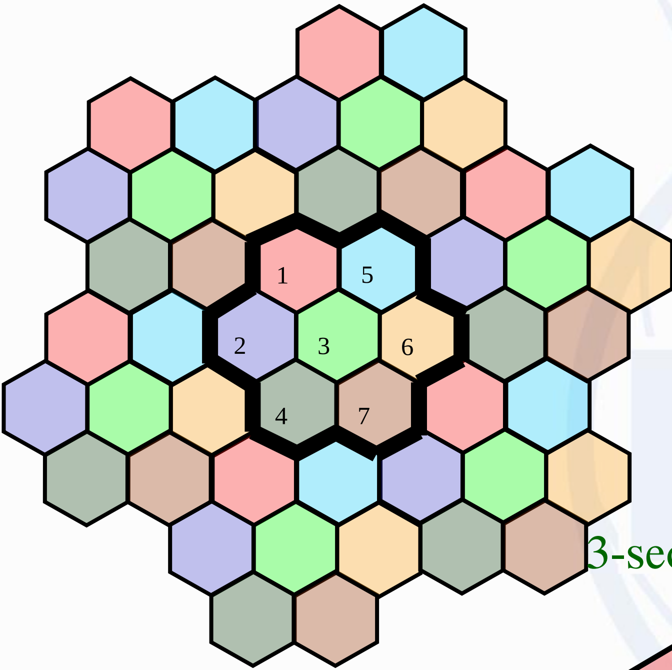
AS	Application server
BS	Base station
DB	Database
GW	Gateway
RN-GW	Radio network gateway
RS	Relay station
UNI	User-network interface
UT	User terminal
WASN network	Wide area sensors and/or actuators
WN-GW	Wired network gateway
WT	Wireless terminal
WT-MS	WT management server



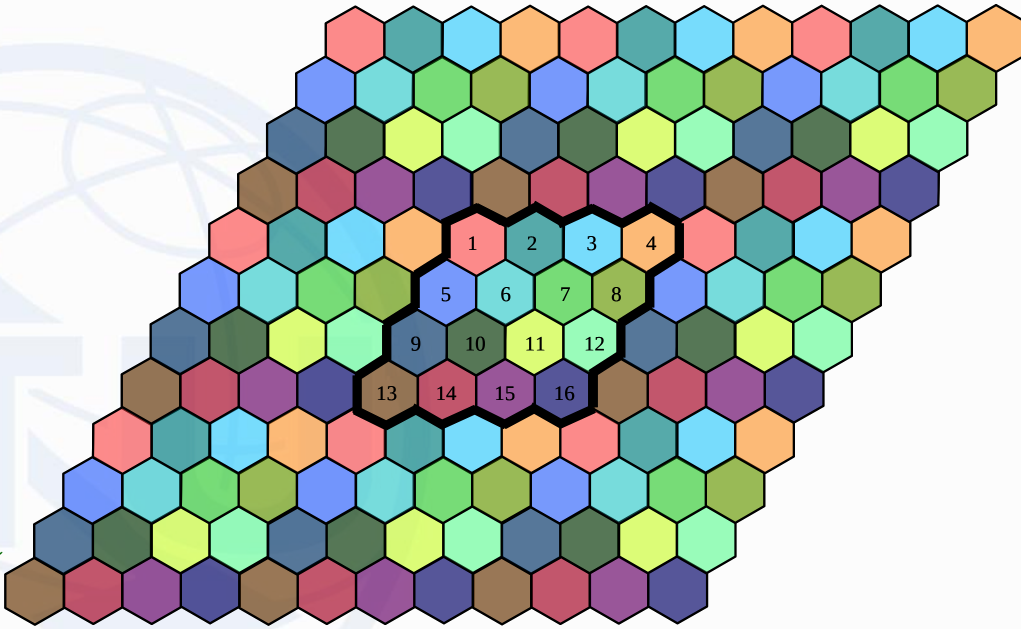
WASN cell configuration

Figures 3, 4, 5: Report ITU-R M.2224

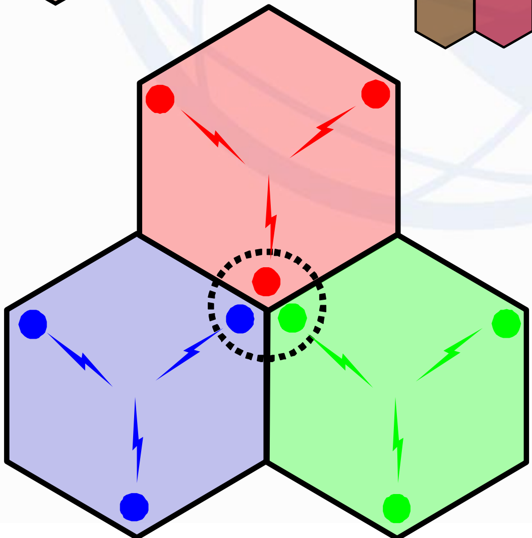
cluster size of 7



cluster size of 16

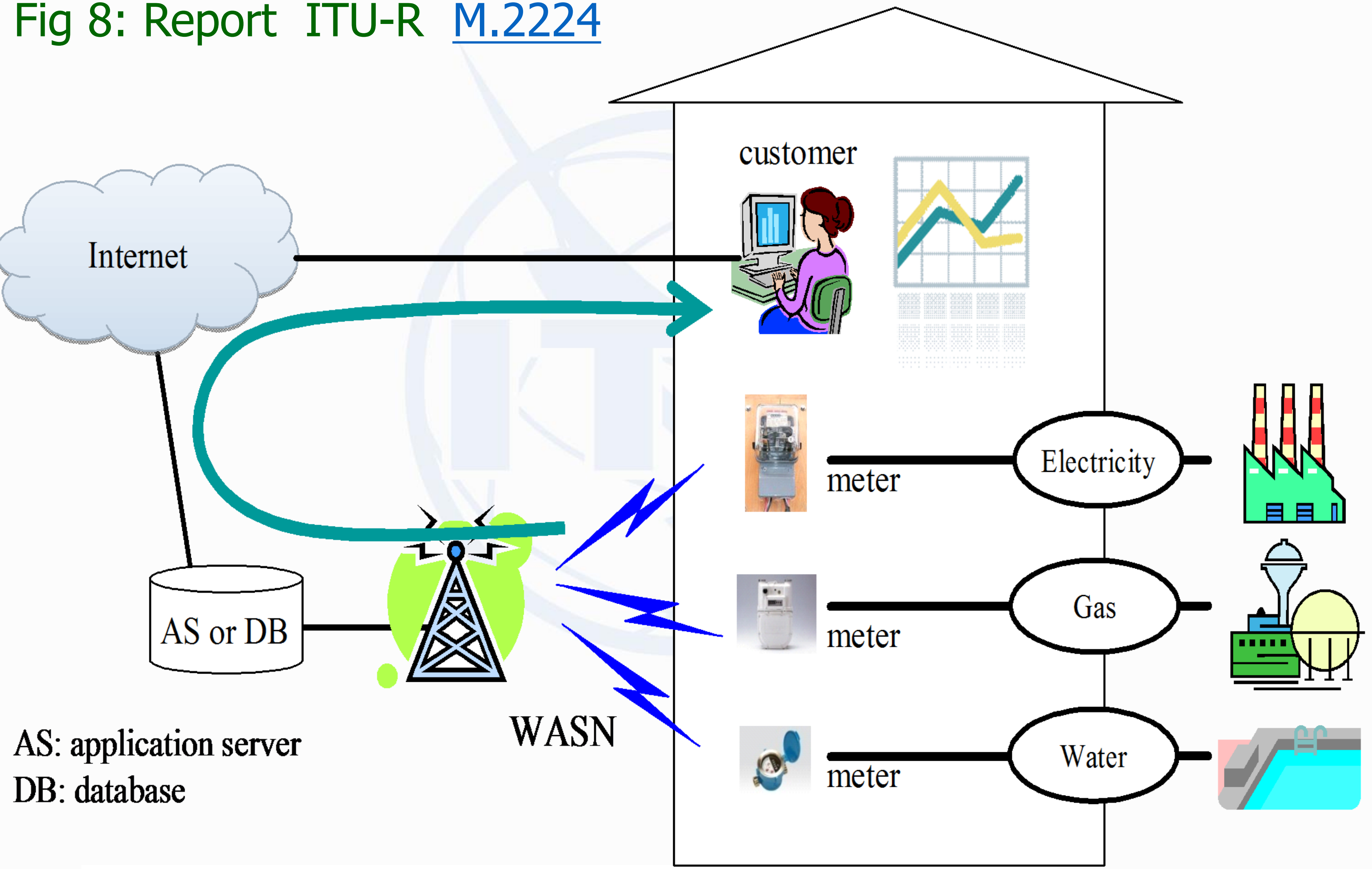


3-sector antenna



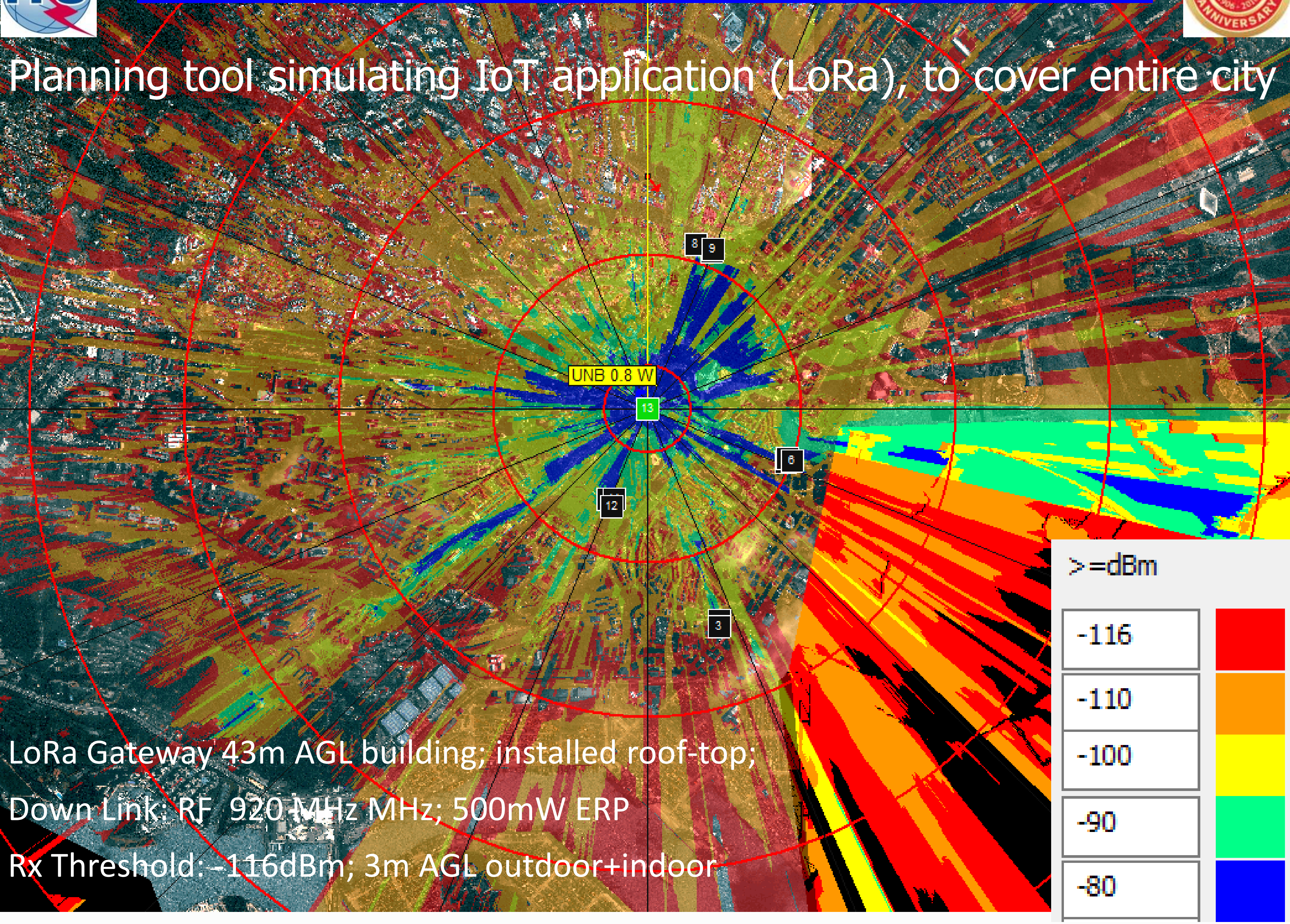
WASN, home energy consumption

Fig 8: Report ITU-R M.2224



ATDI coverage predictions

Planning tool simulating IoT application (LoRa), to cover entire city



LoRa Gateway 43m AGL building; installed roof-top;

Down Link: RF 920 MHz MHz; 500mW ERP

Rx Threshold: -116dBm; 3m AGL outdoor+indoor

Typical Smart House: Z-Wave

designed mainly for remote controls, smoke alarms and security sensors

- Z-Wave uses a single frequency FSK
- Data rate up to 100 Kbps; unlike IEEE 802.11, designed primarily for high-bandwidth data flow
- Range between controllers & slave devices up to 100 ft

Country/Region	Standard	Z-Wave RF
Australia	AS/NZS 4268	921.4 MHz
Brazil	ANATEL Resolution 506	921.4 MHz
CEPT	EN 300 220	868.4 MHz
Chile	FCC CFR47 Part 15.249	908.4 MHz
China	CNAS/EN 300 220	868.4 MHz
Hong Kong	HKTA 1035	919.8 MHz
India	CSR 564 (E)	865.2 MHz
Israel	MoC Wireless Act	915-917 MHz
Japan 950 (obsolete by end of 2015)	ARIB T96	951-956 MHz
Japan 920 (since Feb 2012)	ARIB STD-T108	922-926 MHz
Malaysia	SKMM WTS SRD/EN 300 220	868.1 MHz
Mexico	FCC CFR47 Part 15.249	908.4 MHz
New Zealand	AS/NZS 4268	921.4 MHz
Russia	GKRCh/EN 300 220	869.0 MHz
Singapore	TS SRD/EN 300 220	868.4 MHz
South Africa	ICASA/EN 300 220	868.4 MHz
Taiwan	NCC/LP0002	922-926 MHz
UAE	EN 300 220	868.4 MHz
USA/Canada	FCC CFR47 Part 15.249	908.4 MHz

Author's relevant presentations

1. International, regional & national regulation of SRDs at ITU Workshop on SRDs, Geneva 3 June 14

2. International, Regional and National regulation of Electronic Devices and SRD's at Telecommunication Certification Body, Council, 15 April15, Baltimore MD; US

3. January 2016_SRD_Mazar_China & Singapore.pdf

4. More info at new Wiley book https://www.amazon.com/Radio-Spectrum-Management-Regulations-Techniques/dp/1118511794

Any Questions?