SHORT RANGE WIRELESS CONNECTIVITY FOR HEALTH AND WELLNESS – DRAFT V0.1

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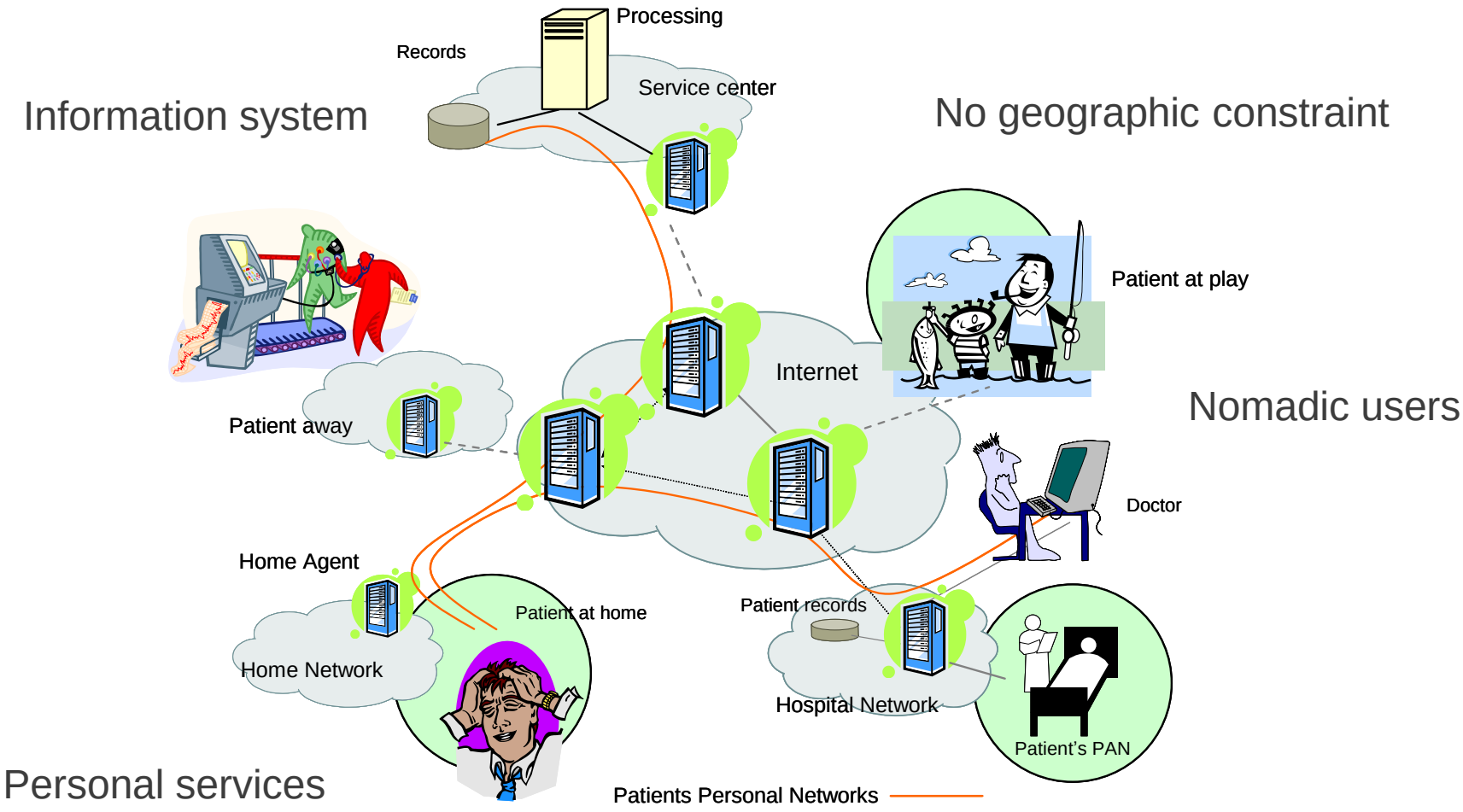
OUTLINE

- System overview
- Example applications and requirements
- Frequency bands and regulatory issues
- Short range wireless solutions
- What is missing?
- Concluding remarks and way forward

THE BIG PICTURE: EXAMPLE HEALTH AND WELLNESS SERVICES SYSTEM



Leverage existing systems and infrastructure and fill gaps as needed.

A SERVICE WALK THROUGH: THE ELEMENTS 1/2

- Communication forward link
  - **Patients personal sensor devices** supporting one or more health applications
  - **BAN** consisting of **wearable** or **implantable** sensor devices
  - Personal sensor devices **secure mobile gateway**
  - Secure mobile gateway to **WAN** (e. g. cellular network)
  - WAN to **eHealth service infrastructure** (e. g. routers, healthcare information system)
  - Data stored in **healthcare databases** for **evaluation** and **diagnostic aids**
- Communication return link
  - Secure **healthcare provider access** to eHealth infrastructure
  - Healthcare provider **monitoring**
  - Healthcare provider **request** for additional information
  - Automated request for additional information (e.g. measurements)
  - Healthcare provder **control** signal

A SERVICE WALK THROUGH: THE ELEMENTS 2/2

- Initialization and Control
  - Setup (i.e., BAN devices, short range link establishment)
  - Network entry (i.e. BAN and BAN-WAN)
  - Routing, ad-hoc networking, service discovery
    - ✓ update routing tables (e.g. in mobile gateway)
    - ✓ remote service discovery
    - ✓ Maintaining end-to-end QoS
  - Security (e.g. AAA, IPSec)
  - …

To be completed

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EXAMPLE IMPLANTABLE BAN APPLICATIONS

- Sensor
  - Implanted glucose sensor
  - Sugar density
  - Cardiac arrhythmia monitor/recorder
  - Brain liquid pressure sensor
  - Wireless capsule endoscope (gastrointestinal)
  - Wireless capsule for drug delivery
- Stimulator
  - Deep brain stimulator
  - Cortical stimulator
  - Visual neuro-stimulator
  - Audio neuro stimulator
- Stimulator continued
  - Parkinson's disease
  - Epilepsy stimulator
- Brain-computer interface
- Remote control of medical devices
  - Pacemaker
  - ICD Implantable
  - Cardioverter Defibrallitor actuators
  - Insulin pump
  - Hearing aid (wearable and implanted)
  - Retina implants

Source: IEEE SG-BAN*15-07-0735-06-0ban-ban-application-matrix.xls*

EXAMPLE WEARABLE BAN APPLICATIONS

- EEG Electro Encepalography
- ECG Electro Cardiogram
- EMG Electromyography (muscular)
- Vital signals monitoring
- Temperature (wearable thermometer)
- Respiratory monitor
- Wearable heart rate monitor
- SpO2 wearable pulse oximeter
- Wearable blood pressure monitor
- Oxygen pH value
- Wearable glucose sensor
- Muscle tension sensing and stimulation
- Wearable weighing scale
- Fall detection
- Sports aids

Source: IEEE SG-BAN, *15-07-0735-06-0ban-ban-application-matrix.xls*

EXAMPLE REQUIREMENTS FOR NOMADIC BAN: LDR DIABETES SCENARIO

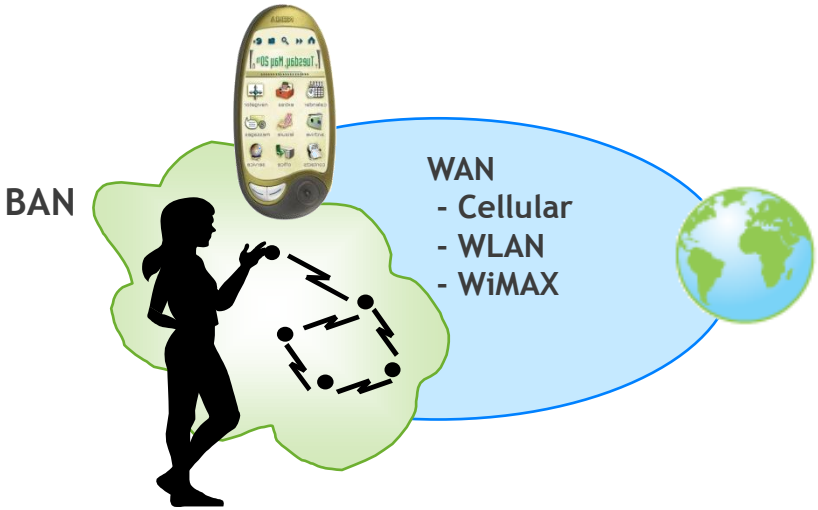
Sensor transmit data[1]

Sensor receive control[2]

Device no.	Type	Data block size	Block rate	Data rate
0	Coordinator (receiver)	Arbitrary	Arbitrary	Arbitrary
1	Blood pressure sensor	64 bit	1 block/minute	< 100 bps
2	ECG sensor[3]	1024 bit	10 blocks/second	10.24 kbps
3	Respiratory sensor	64 bit	10 blocks/second	640 bps
4	Clinical thermometer	8 bit	1 block/second	< 100 bps
5	Pulse sensor (ear)	8 bit	1 block/second	< 100 bps

1. Based on the MAGNET Diabetes scenario
2. Nominally, a few bytes per control message, 1 message per minute
3. When transmitting. In this example, operation 1 min out of every 10 is considered, on average.

HIGH LEVEL REQUIREMENTS FOR SHORT RANGE WIRELESS BAN COMMUNICATION



Source: MAGNET

Unrestricted in geographic span!

- Short range communication (≤3 m)
- Low power consumption (potentially energy scavenging)
- Low cost
- QoS (10^{-3} - 10^{-6} BER)
- Robust and reliable
- Worldwide, go anywhere (EU, US, JP)
- Good coexistence
- Small form factor (e.g. wearable)
- Trusted and secure
- Precise localisation not required

Low power, low cost, yet robust and secure short range solutions are needed for supporting health and wellness applications operating anytime, anywhere

WHAT DO WE NEED TO KNOW?

- Data rate (e.g. high, med, low)
- Link type
  - Symmetric or asymmetric
- No. of devices per piconet
  - e.g. high, med, low
- Duty cycle (application)
- Radio range
- Coexistence
- Network (e.g. topology)
- Robustness/reliability
- Power consumption
- Autonomy
- Power delivery (e.g. energy scavenging)
- QoS (e.g. BER, latency)
- Setup time
- Mobility (e.g. handover)
- Security and privacy
- Channel
- Regulatory (e.g. EU, US and Asia)
- Form factor
- Location awareness
- Cost

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OVERVIEW OF FREQUENCY BANDS FOR HEALTH AND WELLNESS APPLICATIONS

- Implantable:
  - RFID: 125 KHz, 13.56-27 MHz
  - MICS: 402-405 MHz
  - Other: e.g. 477 MHz, 2 MHz (HF)

To be completed

- Non-implantable[1]:
  - HF: 13.56 MHz (RFID)
  - UHF (unlicensed ISM): 433 MHz band (EU), 868 MHz band (EU), 902-928 MHz (US), 960 MHz band (JP), 2.4-2.4835 GHz
  - UHF (WMTS): 608-614 MHz, 1395-1400 MHz, 1429-1432 MHz
  - SHF (unlicensed ISM): 5.725-5.875 GHz, 3.1-10.6 GHz (UWB)
  - EHF and above: 60 GHz, TeraHertz (e.g. 270 GHz)

Significant variations exist between regions. Regulatory issues remain to be resolved. Common bands for worldwide operation are desirable.

1. May also be considered for implantable devices

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SHORT RANGE WIRELESS SYSTEMS

- RFID
  - Active
  - Passive
- BAN/PAN/WSN
  - Narrowband (e.g. Bluetooth, IEEE802.15, WiBree, 868 MHz systems)
  - Ultrawideband (e.g. IEEE802.15.3, IEEE802.15.4a, FM-UWB)
- WLAN
  - Narrowband (e.g. IEEE802.11x)
  - Ultrawideband (e.g. IEEE802.15.3 (MBOA), IR-UWB)
- Inductive

Wide range of existing and emerging solutions; standard and proprietary.
Suitability for BAN depends on user operating scenarios, applications, etc...

A COMPARISON OF SHORT RANGE, LDR WIRELESS SYSTEMS: BAN/PAN/WSN

Parameter	Bluetooth[2] (ISM 2.4-2.4835 GHz)	ZigBee[2] (2.4 – 2.483 GHz)	ISM 433/860 MHz[2]	FM-UWB[1] (4.2-4.8 GHz/7.25-8.5 GHz)	IR-UWB[2] (4.2-4.8 GHz/7.25-8.5 GHz)
Power consumption	Tx = 25-40 mW, 100 mW Rx = 30-50 mW, 100 mW	Tx = 20-30 mW Rx = 25-40 mW	Tx = 80 mW Rx = 30 mW	Tx = 3.5 mW (1GHz BW) Rx = 7.5 mW	Tx = 3.5 mW Rx = 150 mW
Radiated power	1 mW (Power class 3) 2.5 mW (Power class 2) 100 mW (Power class 1)	1-100 mW (Europe) 1 W (USA)	10-30 mW	<100 μW (1GHz bandwidth)	<100 μW (1GHz bandwidth)
Data rate	723.2 kbps	250 kbps	Up to 62.5 kbps	100 kbps	256 kbps
Multiple users	8 active users	Up to 255 devices per network, 16 RF channels	2 in FDMA mode, others in TDMA mode	15 @ 100 kbps 150 @ 1 kbps	Up to 255 devices per network based on the IEEE802.15.4 MAC
Modulation	FSK	FSK, MSK, O-QPSK	Analogue FSK/FM	Analog FSK/FM	PPM
Medium access	FHMA (Frequency Hopping Multiple Access) TDMA/FH combination	CSMA-CA with TDMA-based beaconing	FDMA or TDMA	FDMA subcarrier w/TDMA IEEE802.15.4, WiseMAC FDMA-like (e.g. 4-6)	IEEE802.15.4
Robustness to interference	Slow frequency hopping, Block code	Symbol-to-chip mapping (32-chip PN sequence), FEC	Possible frequency or band change	Analogue spread spectrum PG = 27 dB (@1GHz BW)	Limited PG
Robustness to multipath	N/A	FEC	Implementation depedent	Wideband Diversity in freq. selective fading (~ 20 dB @ 99% availability)	Wideband Diversity in freq. selective fading (~ 20 dB @ 99% availability)
Range	10 m, 20 m, 100 m	10-100 m	10-30m indoors 1-2km outdoors	1-10 m	10 m indoors 100 m outdoors
Sensitivity	-95 dBm	-90 dBm to -95 dBm	--95t to -115 dBm	-90 dBm	-95 dBm
Capacity	80 MHz	80 MHz	MHz	600 MHz (low band)	600 MHz (low band)

1. Continuous power @ 100 kbps based and 100 μW. Lower power possible dependent on duty cycle, Tx power and BW.
2. Nominal values

CONCLUDING REMARKS AND WAY FORWARD

- System and operating scenarios
- Applications and services
- Requirements
- Potential solutions
- Comparisons
- Gaps

ANNEX