

# Communication Technologies for Smart Objects

Speaker  
Supervisor

Dominik Kovacs  
Matthias Kovatsch

**ETH** zürich

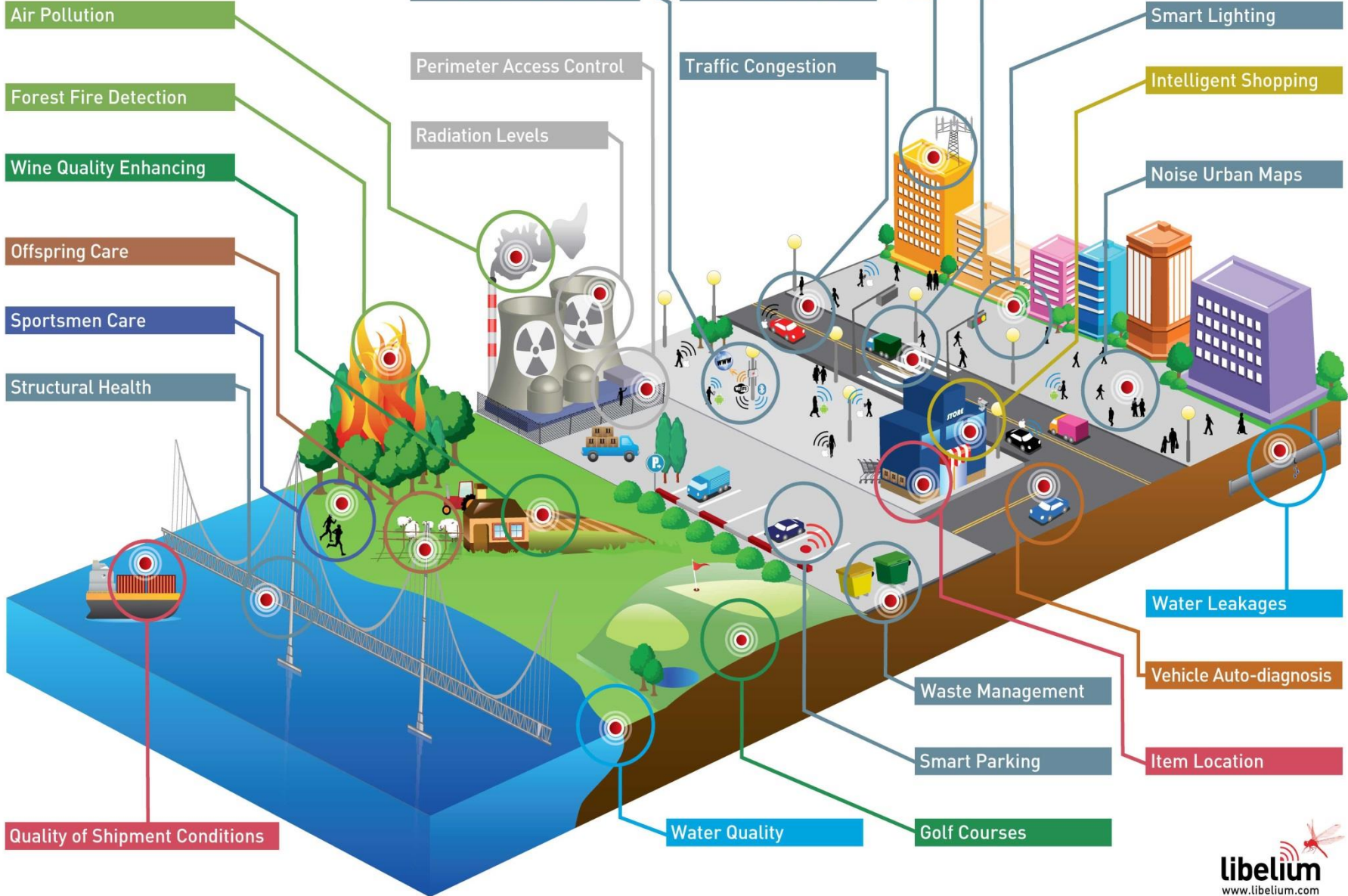
# An Internet of Things

*“In the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit its sensations.”*

– Neil Gross 1999



# Smart Environment



# Check on the Baby



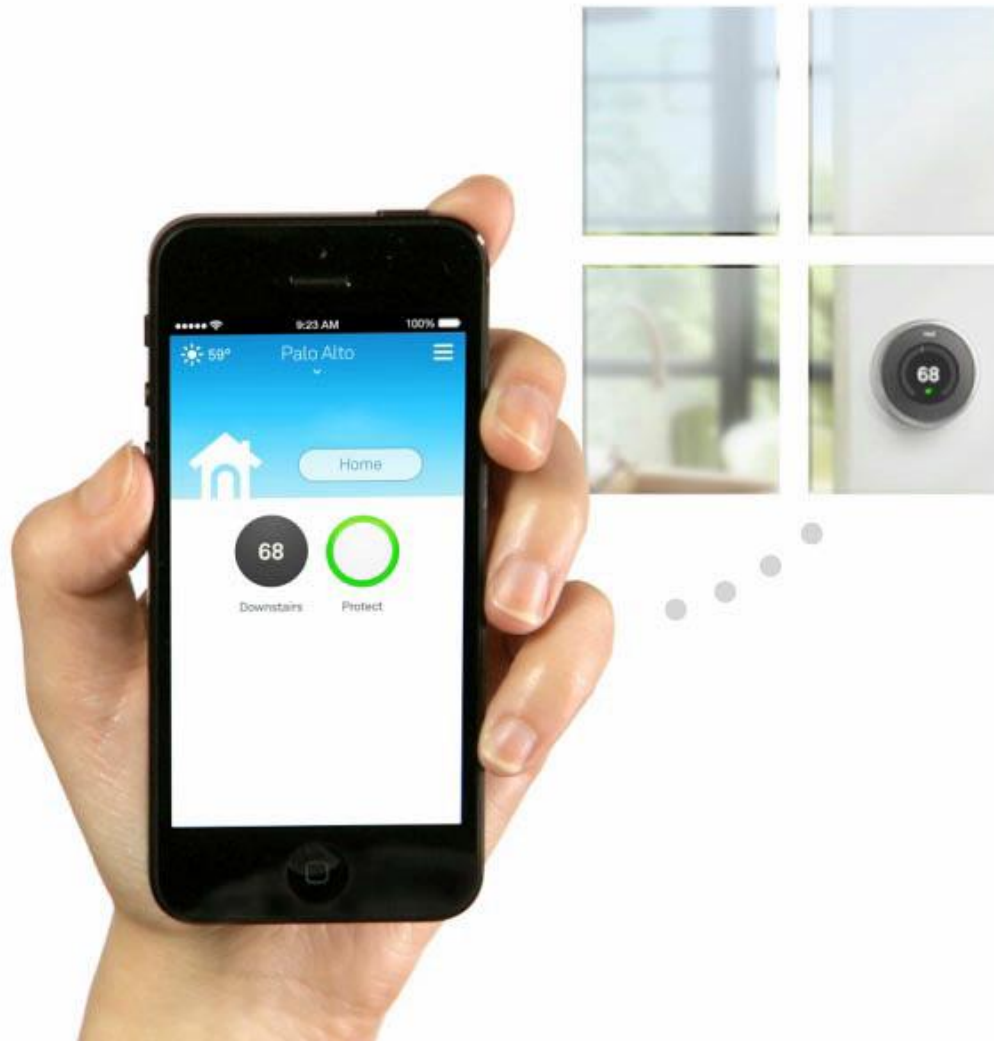
# Monitor an Aging Family Member



# Track your Activity Levels



# Smart Heating



# Wireless Plant Monitoring





# Smart Trash Can

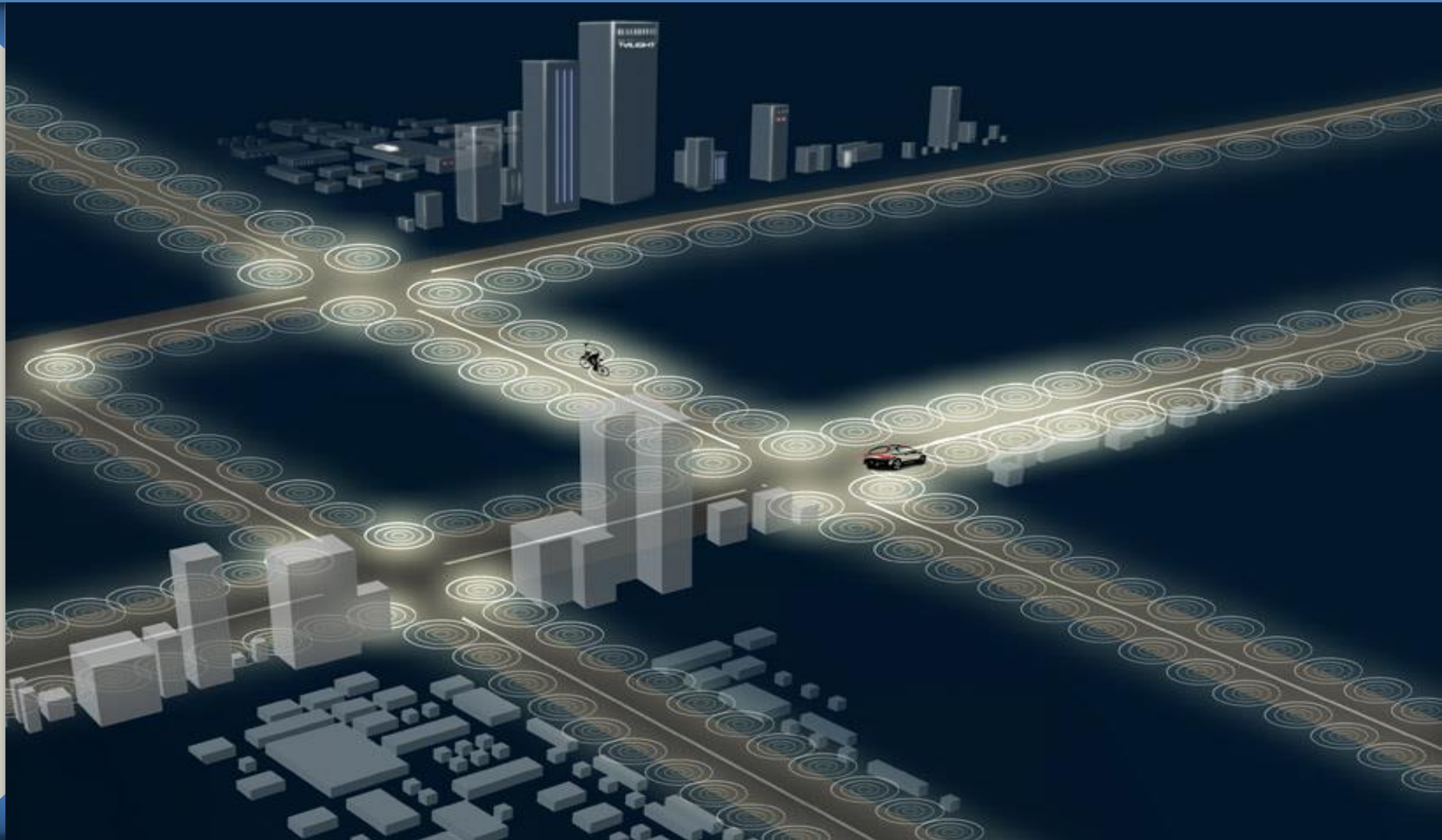


# Smart Trash Can

- Saves Money
- Reduces Litter
- Increases Recycling
- Conserves Fuel
- Reduces Carbon Footprint
- Eliminates Overflows
- Frees Up Labor
- Lowers Tipping Fees



# Smart Street Lighting



# Structure Monitoring

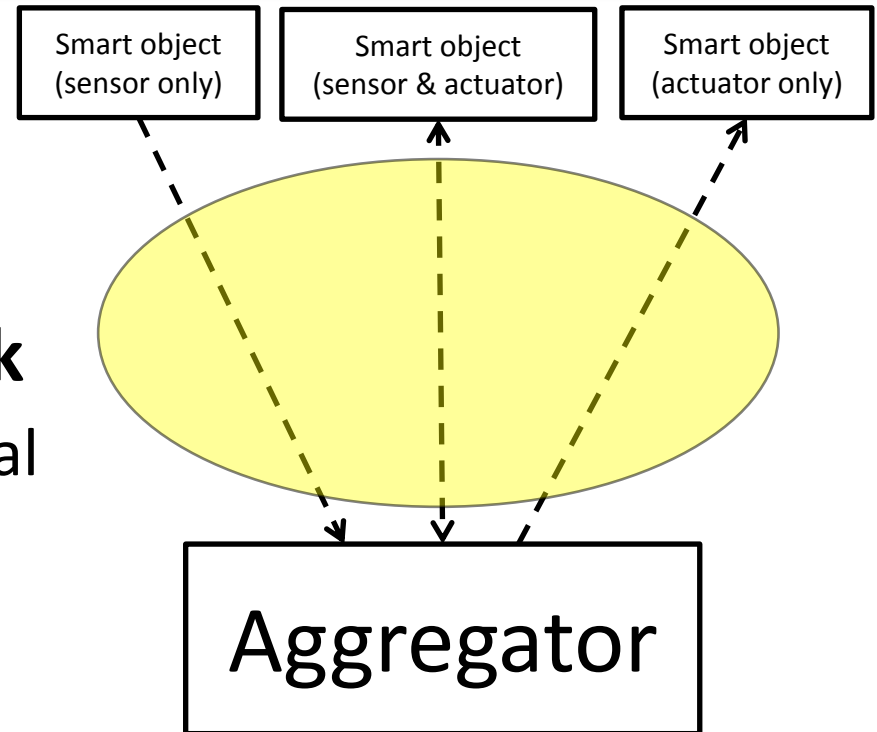


# Floating Sensor Network



# IoT components

- Smart objects
  - sensors, actuators
  - Little bit of processing
- **Communication network**
  - Directional or bidirectional
- Aggregator
  - Collects data
  - Processes data
  - Publishes data



# Motivation

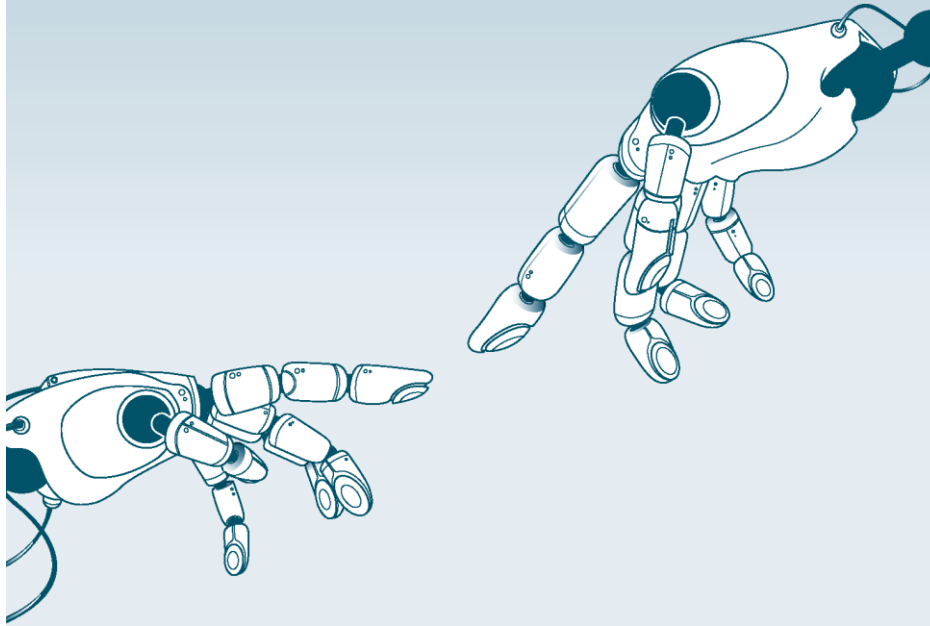
*There are a huge variety of devices and use cases, but no technology fits them all...*

# Outline

- Types of Communication
  - M2M & H2H
- Introduction into Wireless Technology
- Application Domains
  - Body Area Network
  - Smart Home
  - Smart Factory
  - Smart Grid & Logistics



# M2M Definition



- Relationship between two machines
- No human interaction involved
- Triggered by events (e.g. sensor events)

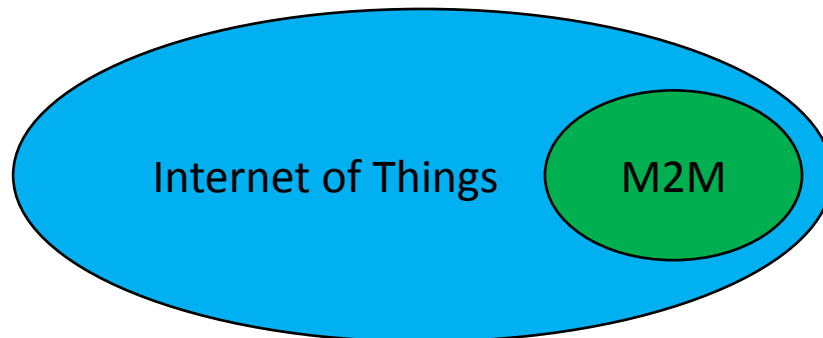
# IoT vs M2M

## Internet of Things (IoT)

- Vision of the Internet of tomorrow
- Requires M2M connectivity

## Machine-to-Machine (M2M)

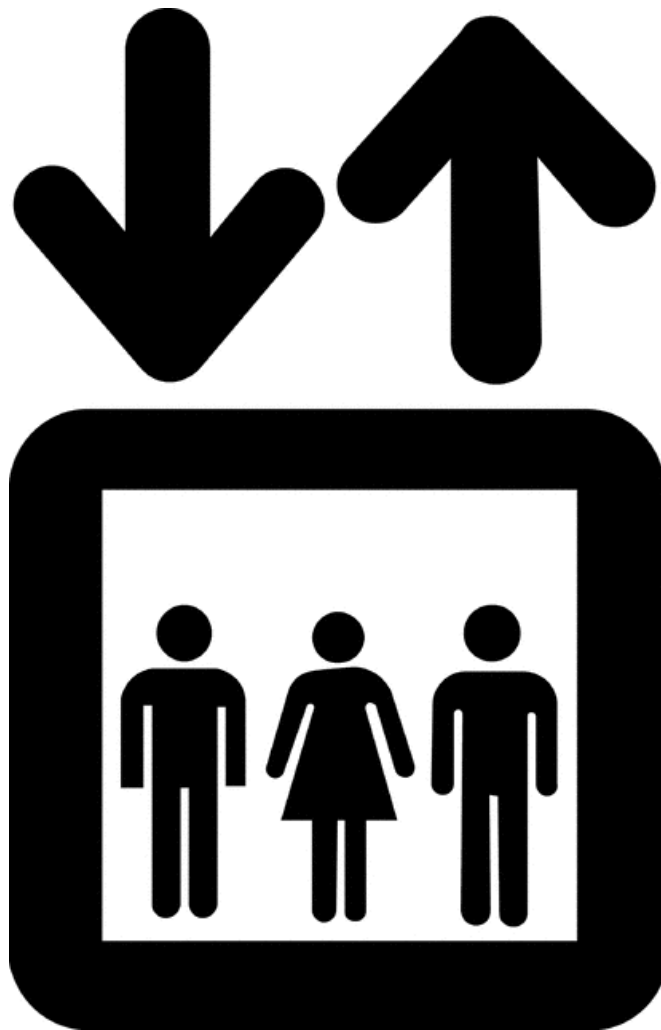
- Communication between machines



M2M as the connectivity of IoT

# M2M or not?

## Some intuition



# M2M or not?

Some intuition



# M2M or not?

## Some intuition



# M2M or not?

## Some intuition



# M2M or not?

## Some intuition

Robert's Fire 1 8:51

Books charles stross Library >

16. **Vortex**  
Robert Charles Wilson  
★★★★★ (23)  
\$12.99

17. **The Forever War**  
Joe Haldeman, John Sc...  
★★★★★ (413)  
\$4.95

18. **The Peace War**  
Vernor Vinge  
★★★★★ (39)  
\$9.99

19. **Axis**

**The Forever War**  
Joe Haldeman, John Scalzi  
★★★★★ (413)  
Digital List Price: ~~\$4.99~~  
Kindle Price: **\$4.95**  
You Save: **\$0.04 (1%)**

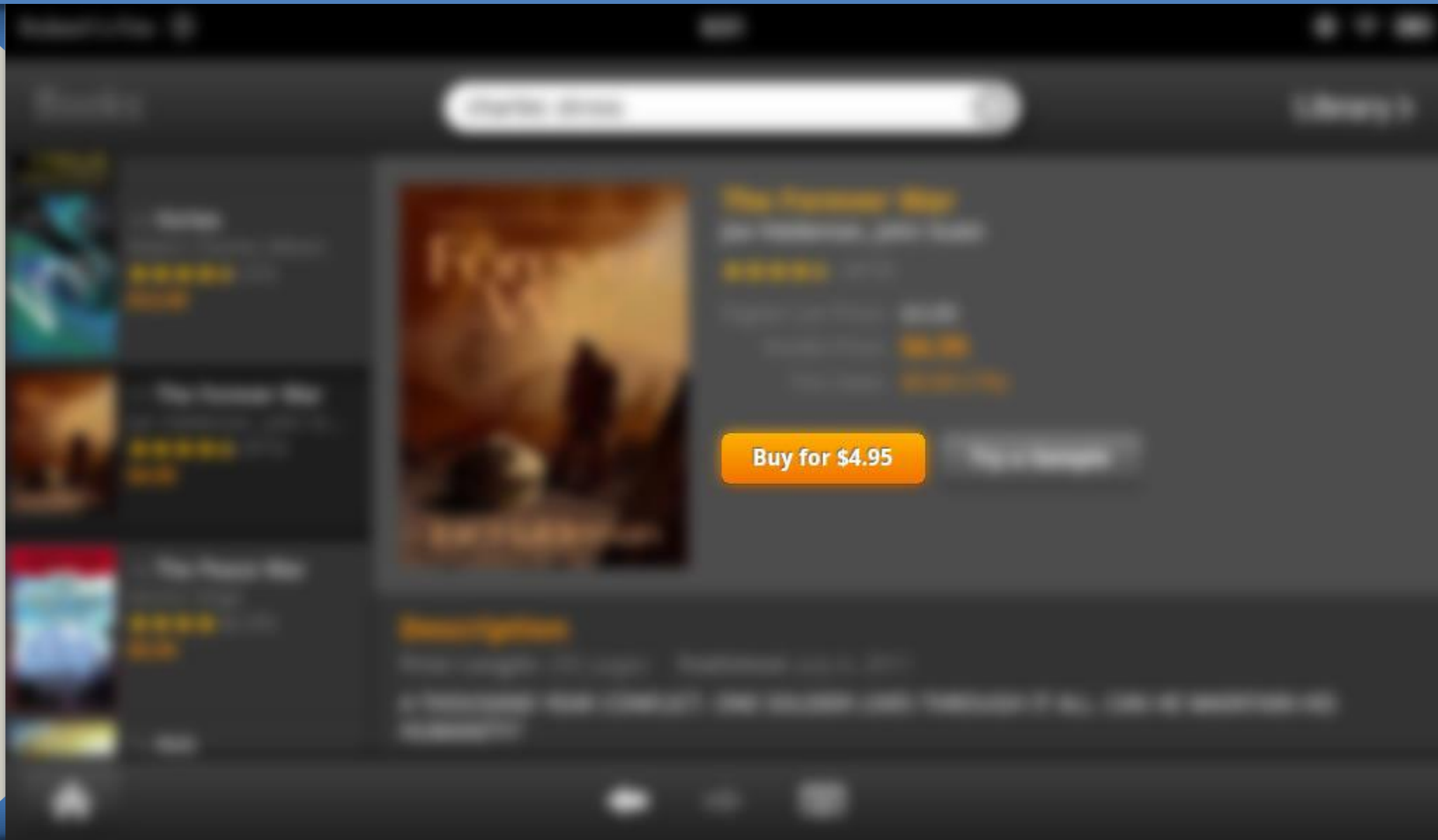
**Buy for \$4.95** **Try a Sample**

**Description**  
Print Length: 292 pages Published: July 6, 2011  
A THOUSAND YEAR CONFLICT. ONE SOLDIER LIVES THROUGH IT ALL. CAN HE MAINTAIN HIS HUMANITY?

Home ← → Menu

# M2M or not?

## Some intuition





# Trivia: Identify Friend or Foe (IFF)

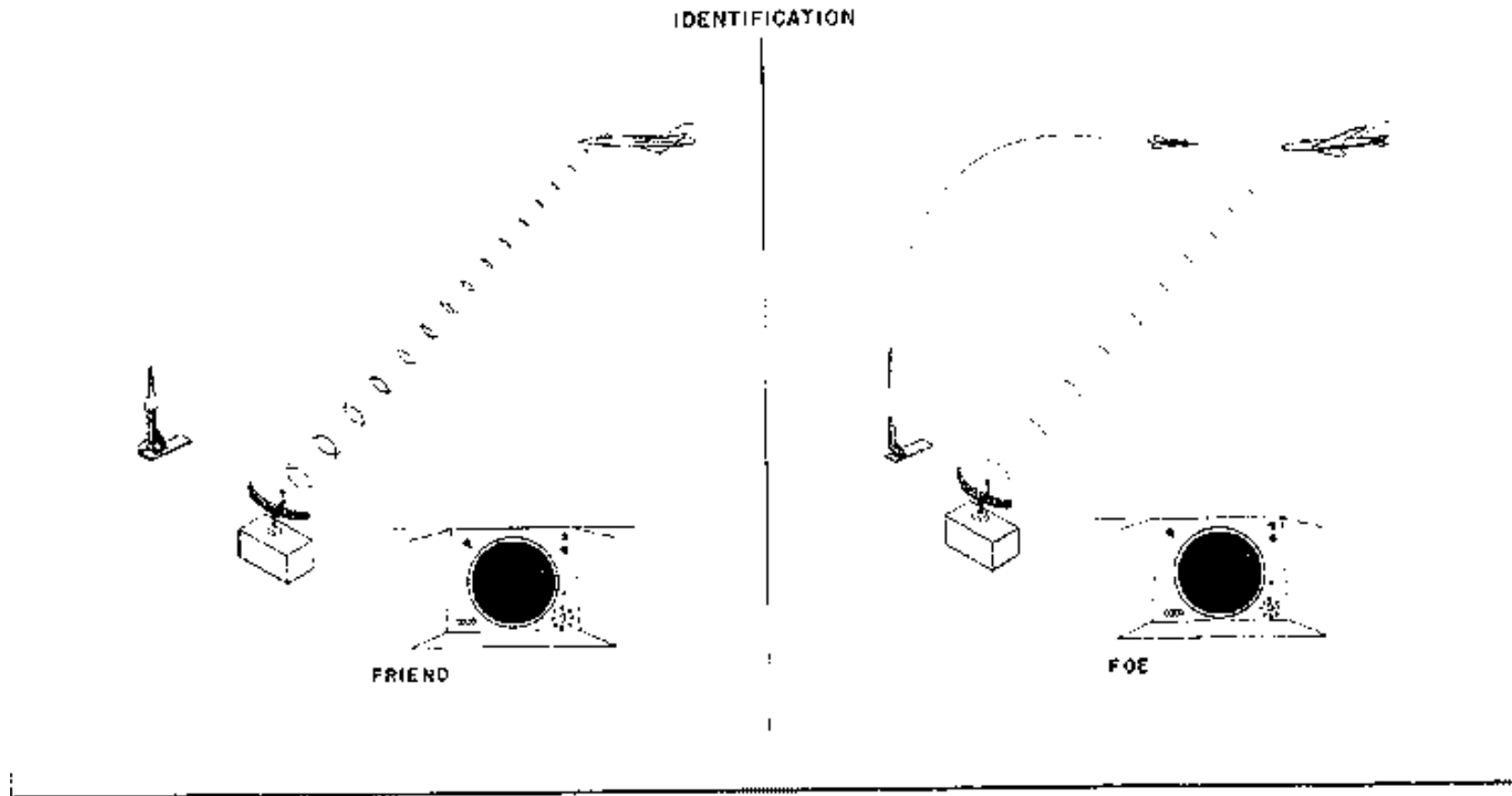
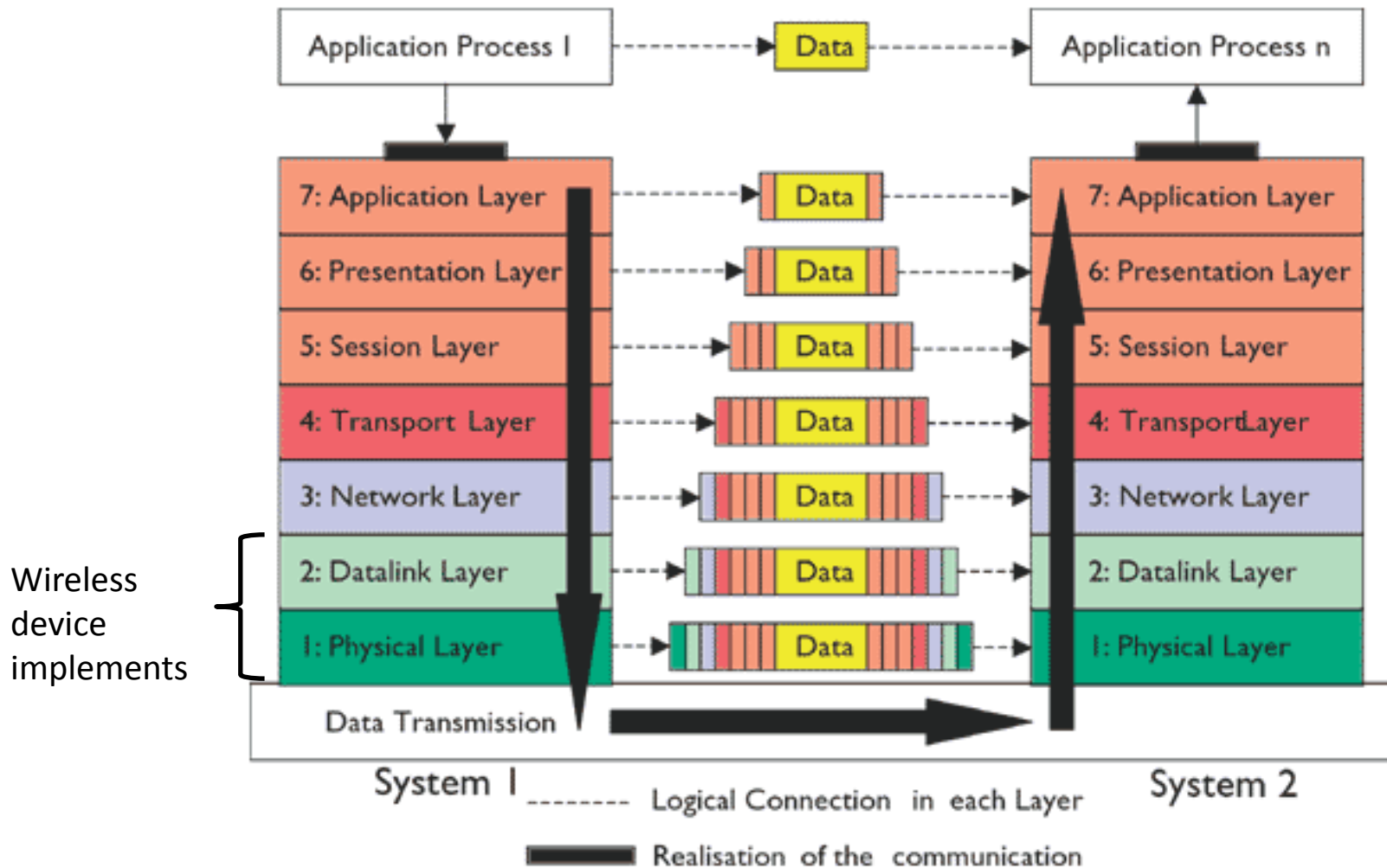


Figure 26. Identification, friend or foe (IFF).

# Focus on Wireless M2M



# OSI Model

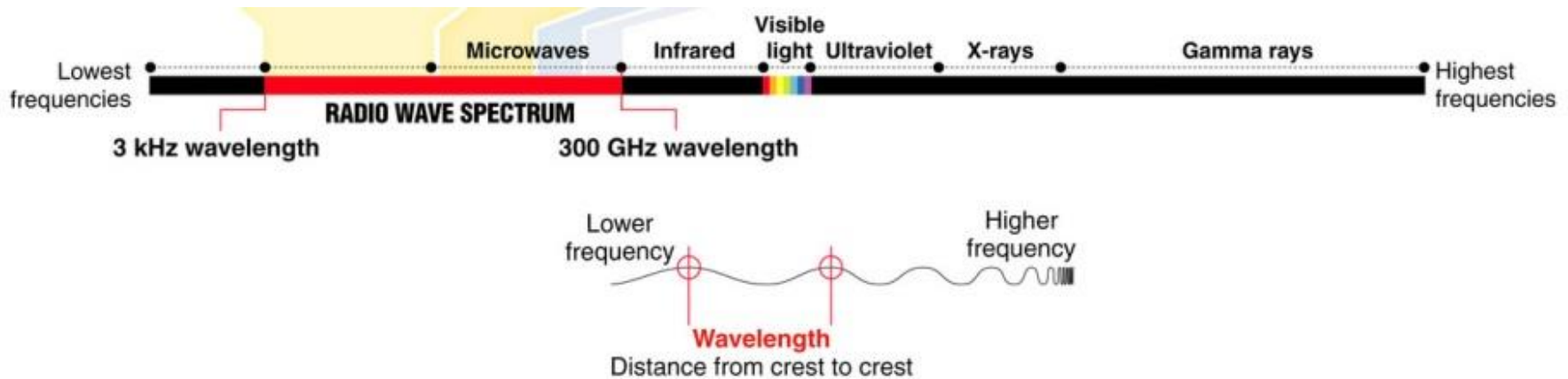


# Wireless Network Difficulties



# Radio Wave Spectrum

## A Limited Resource

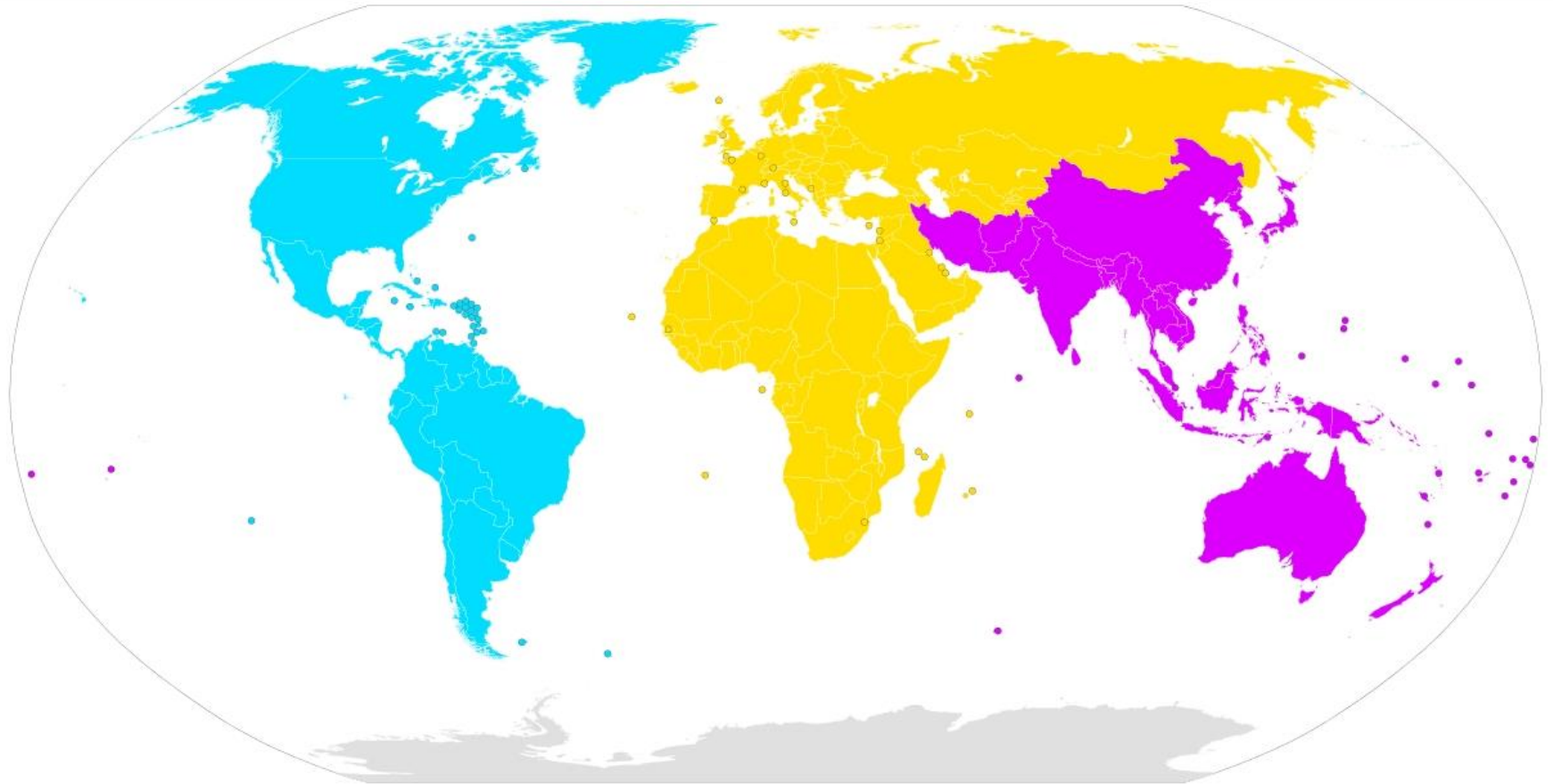


# Trivia: Bandwidth Allocation



- In the US, the Federal Communications Commission (FCC) allocates bandwidth
  - Hearings (before 1982)
  - Lotteries (1980s)
  - Auctions (since the 1990s)

# International Telecommunication Union (ITU) Region



Region 1



Region 2



Region 3

# Industrial, scientific and medical (ISM) radio bands

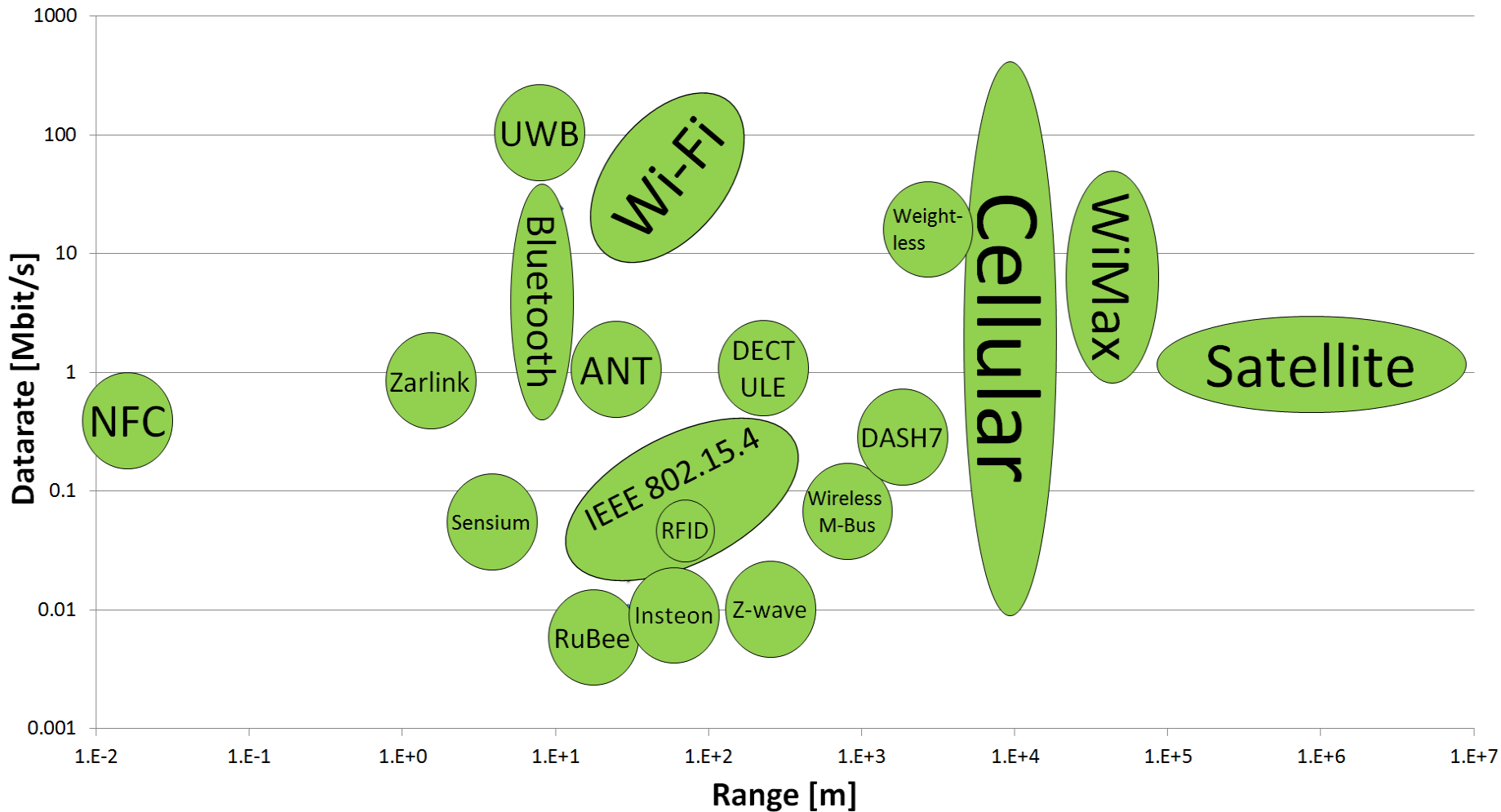
Frequency range		Availability
⋮		
13.553 MHz	13.567 MHz	Worldwide
26.957 MHz	27.283 MHz	Worldwide
40.660 MHz	40.700 MHz	Worldwide
433.050 MHz	434.790 MHz	Region 1 only
902.000 MHz	928.000 MHz	Region 2 only
<b>2.400 GHz</b>	<b>2.500 GHz</b>	<b>Worldwide</b>
5.725 GHz	5.875 GHz	Worldwide
⋮		



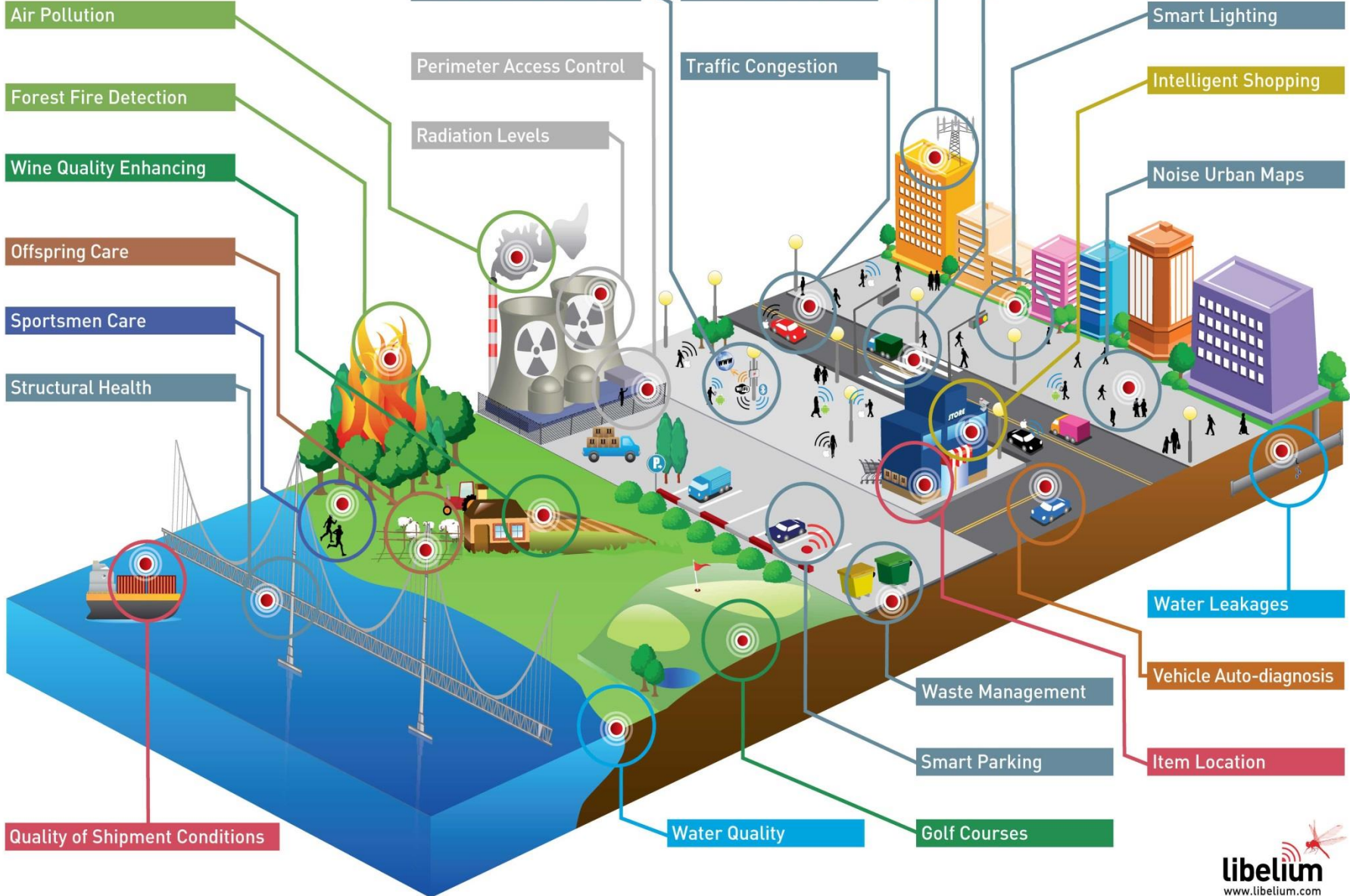
# Wireless Technologies (19)

A word cloud of wireless technologies arranged in a roughly triangular shape pointing to the right. The words are in various colors and orientations. The technologies included are: DASH7, WiFi, Satellite, RuBee, DECT-ULE, WiMax, UWB, Insteon, Weightless, Wireless-M-Bus, Bluetooth, Cellular, IEEE802.15.4, Z-wave, RFID, ANT, NFC, Zarlink, and Sensium.

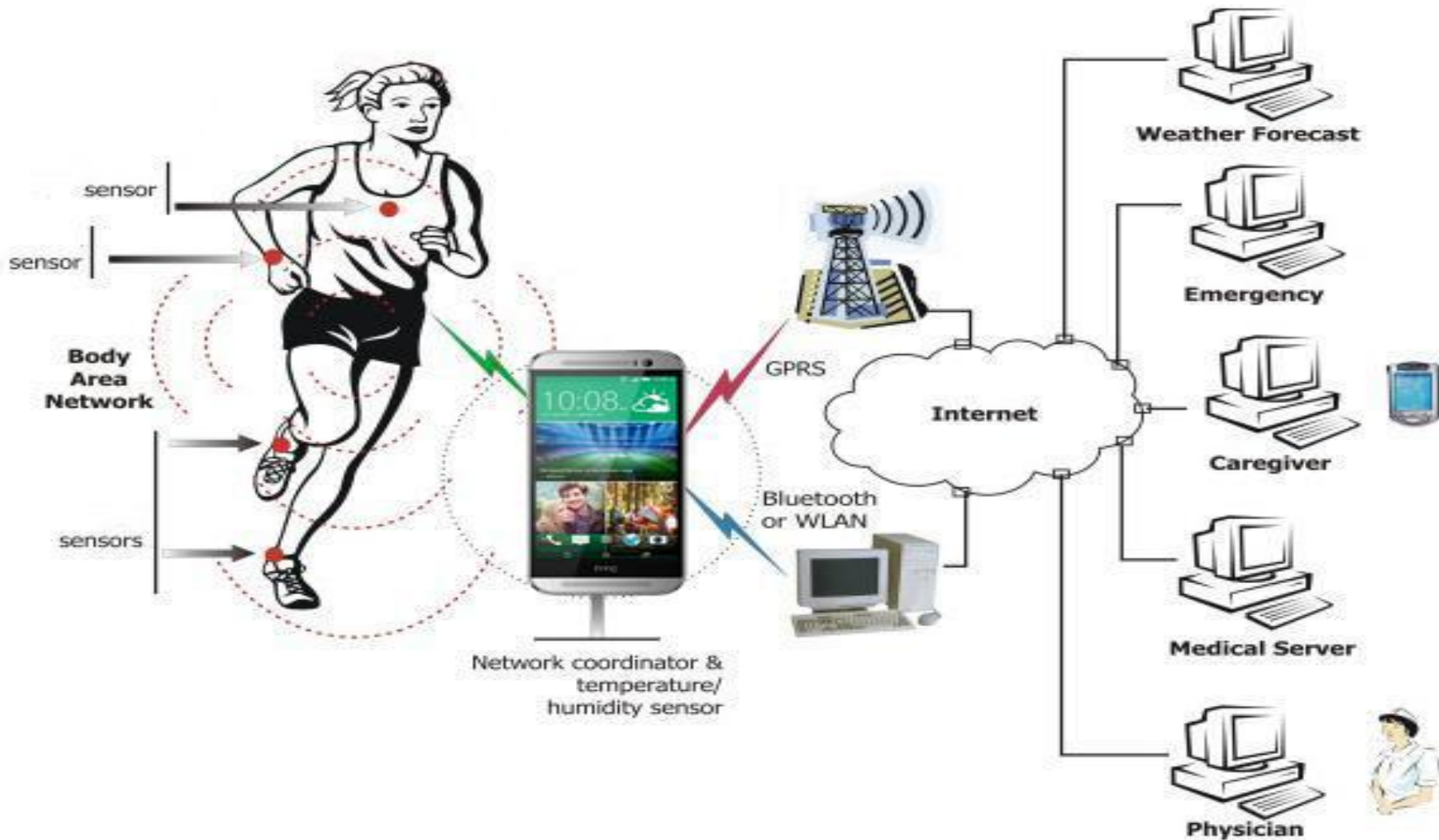
# Datarate-Range Comparison



# Smart Environment



# Body Area Network (BAN)



# Wearables and Implants



Smart Glasses



Sensor in clothes



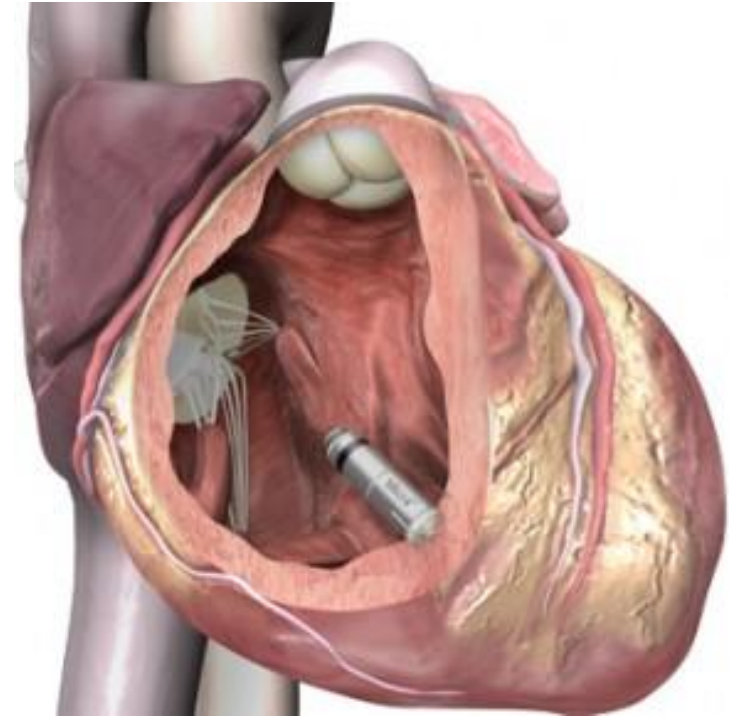
Smart Watches



Smart Skin



Pedometers



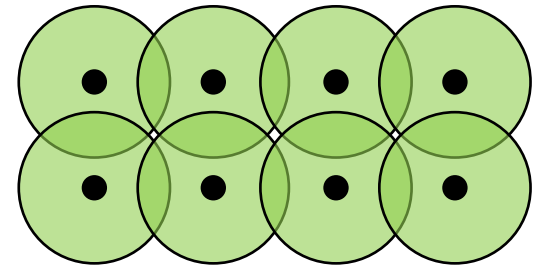
Smart Pacemaker

# BAN Characteristics

- Low CPU power
  - Collecting rather than processing
- Battery operated
  - Mobile
- Small size → Small battery → Low power
- No line of sight (body, clothes)
- **Can be health critical**

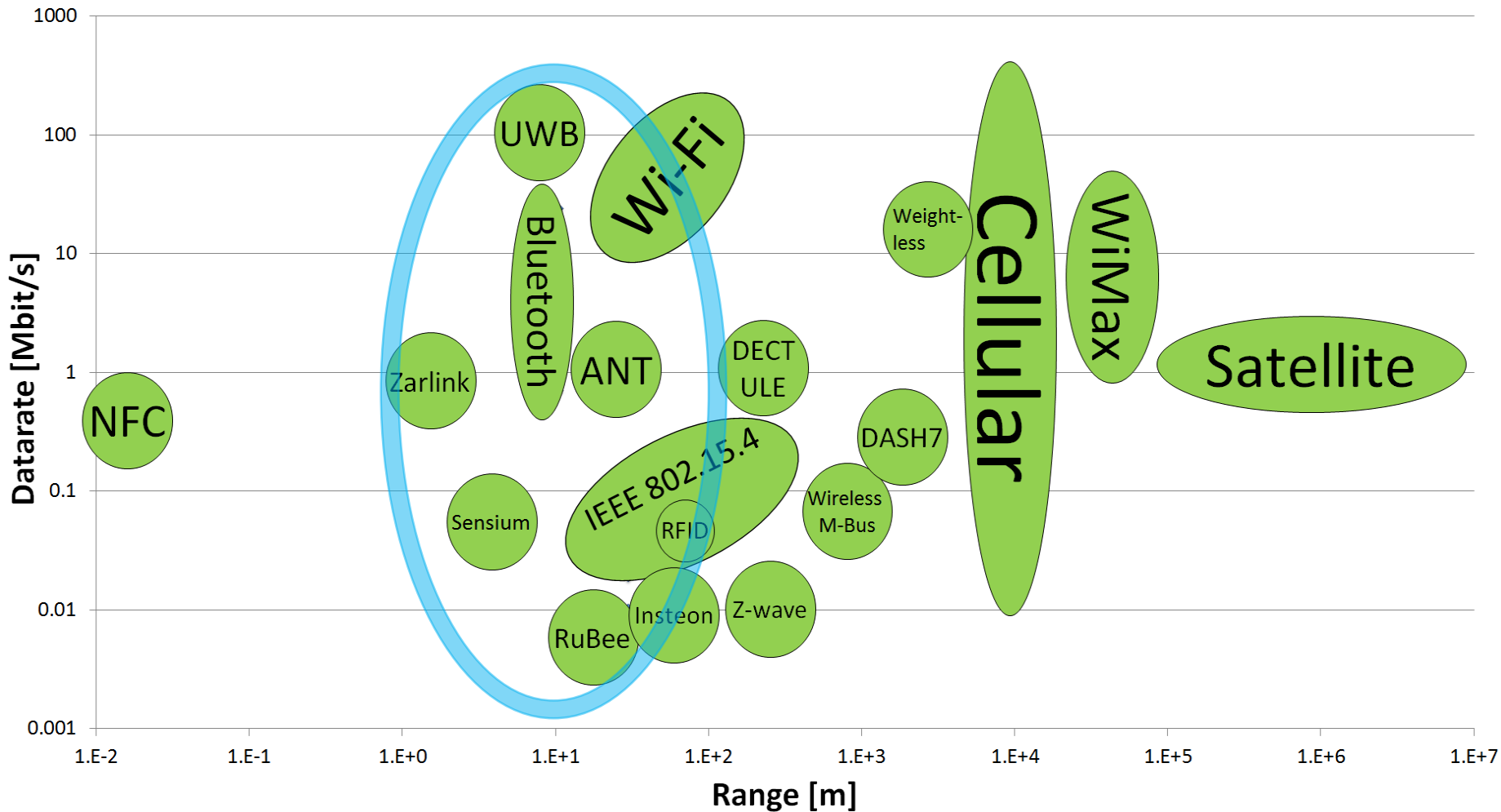
# BAN Communication Requirements

- Power efficient
- Robust against interference
  - Off-body
  - On-body
- Interoperable



Off-body interference

# BAN Wireless Technologies





# BAN Communication Requirements

- Power efficient ✓
- Robust against interference
  - Off-body
  - On-body
- Interoperable

UWB Zarlink  
Sensium  
IEEE802.15.4  
Bluetooth/BLE ANT  
RuBee

# BAN Wireless Technologies (7)

Ultra Wideband  
(UWB)

ANT

Bluetooth/BLE

Sensium

IEEE 802.15.4

RuBee

Zarlink

# BAN Wireless Technologies (7)

Very High Bandwidth Wearables

Low Bandwidth Wearables

High Bandwidth Wearables

Low Bandwidth Wearables

Implants

High Bandwidth Wearables

Low Bandwidth Wearables

# Smart Home

more than just «Home Automation»

- Smart Heating
- Smart Lighting
- Smart Outlets
- Smart Kitchen
- Smart Gardening



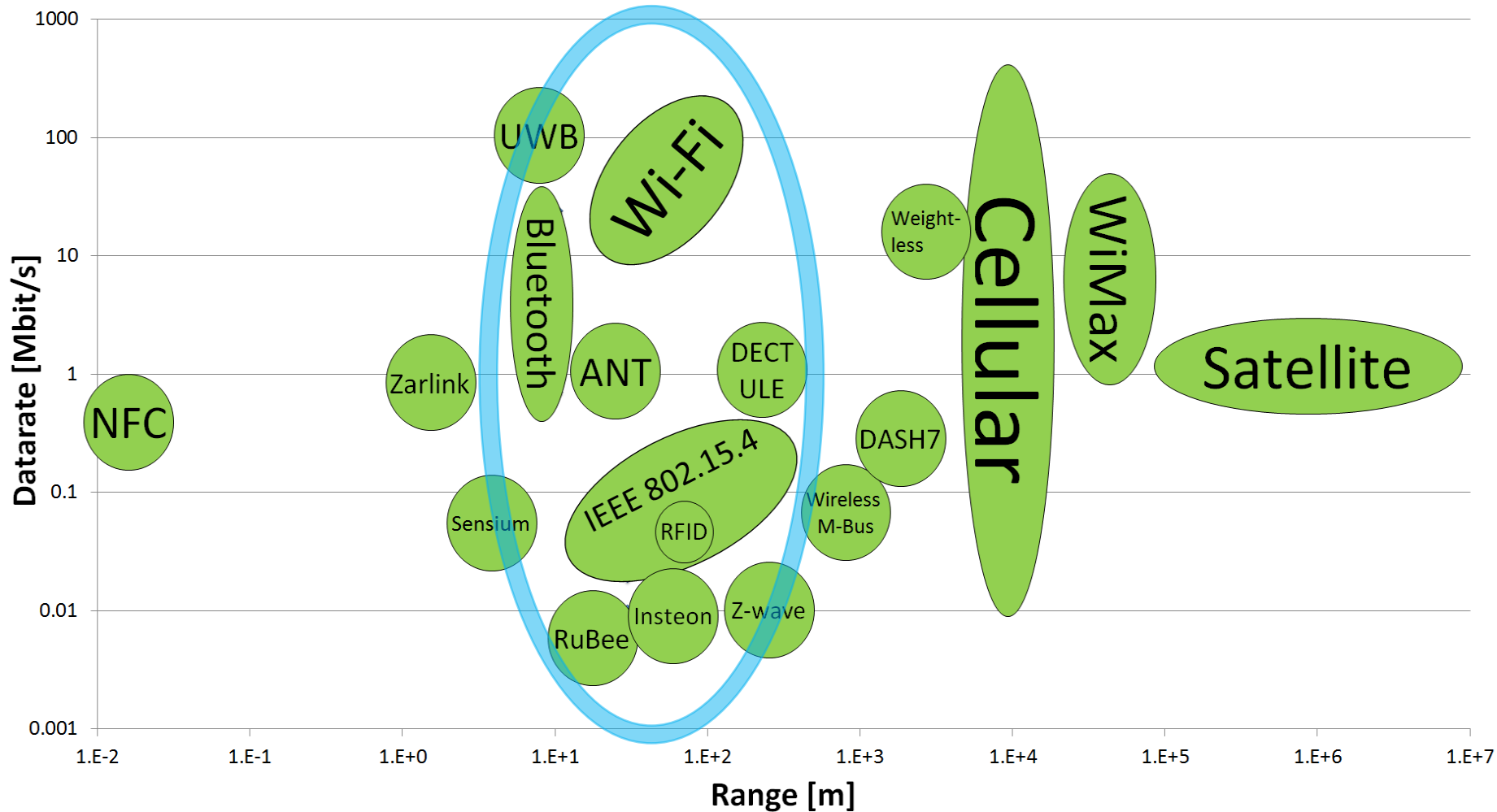
# Smart Home Characteristics

- Stationary
  - But mostly battery operated though
- Low cost
  - Huge Quantity
- (Scalability)
- No line of sight (walls)
- Variety of different applications

# Smart Home Communication Requirements

- Sufficient range
- Variable Bandwidth
- Interoperable

# Smart Home Wireless Technologies



# Smart Home Communication Requirements

- Sufficient range
- Variable Bandwidth
- Interoperable

Insteon  
Z-wave WiFi  
DECT-UL  
LEUWB  
Bluetooth/BLE  
RFID IEEE 802.15.4  
RuBee



# Smart Home Communication Requirements

- Sufficient range
- Variable Bandwidth
- Interoperable



# Smart Home Wireless Technologies (6)

Wi-Fi  
IEEE 802.11n

RFID

RuBee

IEEE 802.15.4

Insteon

DECT ULE

# Smart Home Wireless Technologies (6)

Multimedia-streaming

Access control, Identification

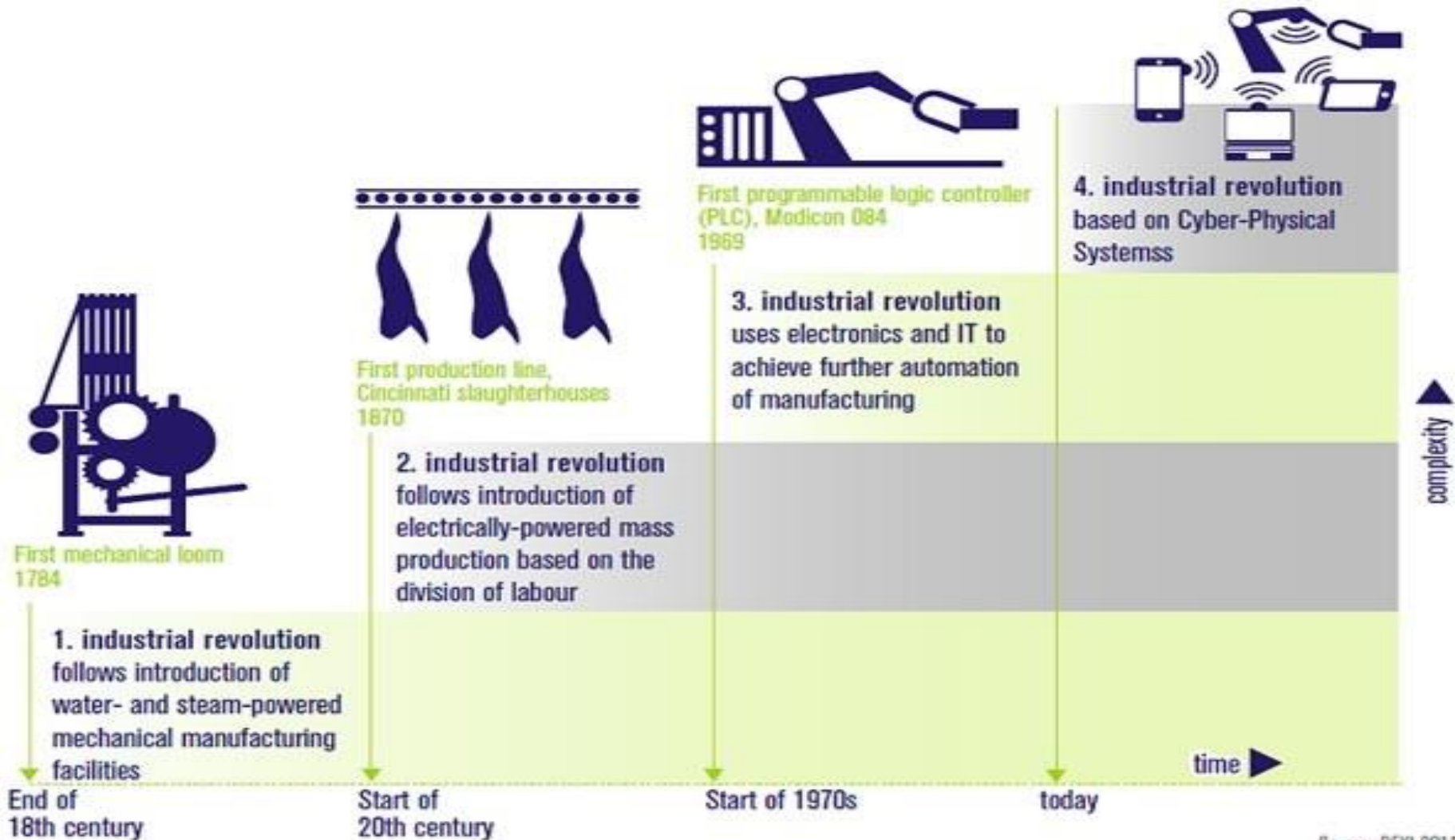
Smart Gardening

Smart Metering  
Home Automation

Home Automation

Smart Metering  
Home Automation

# Smart Factory (Industry 4.0)

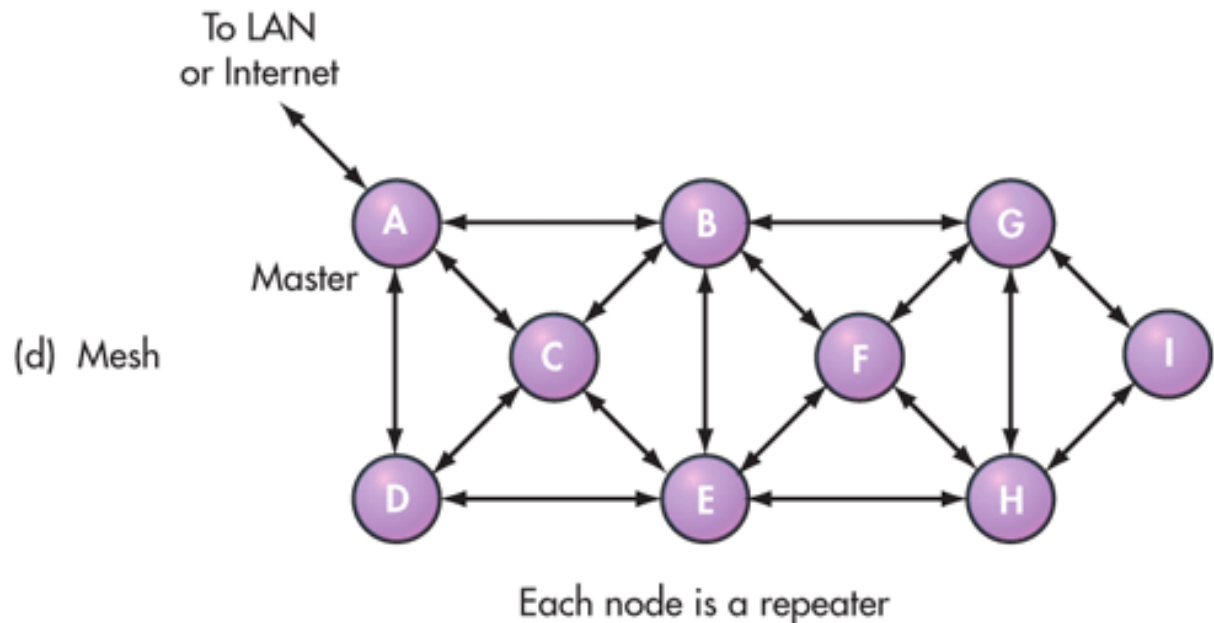


# Smart Factory Characteristics

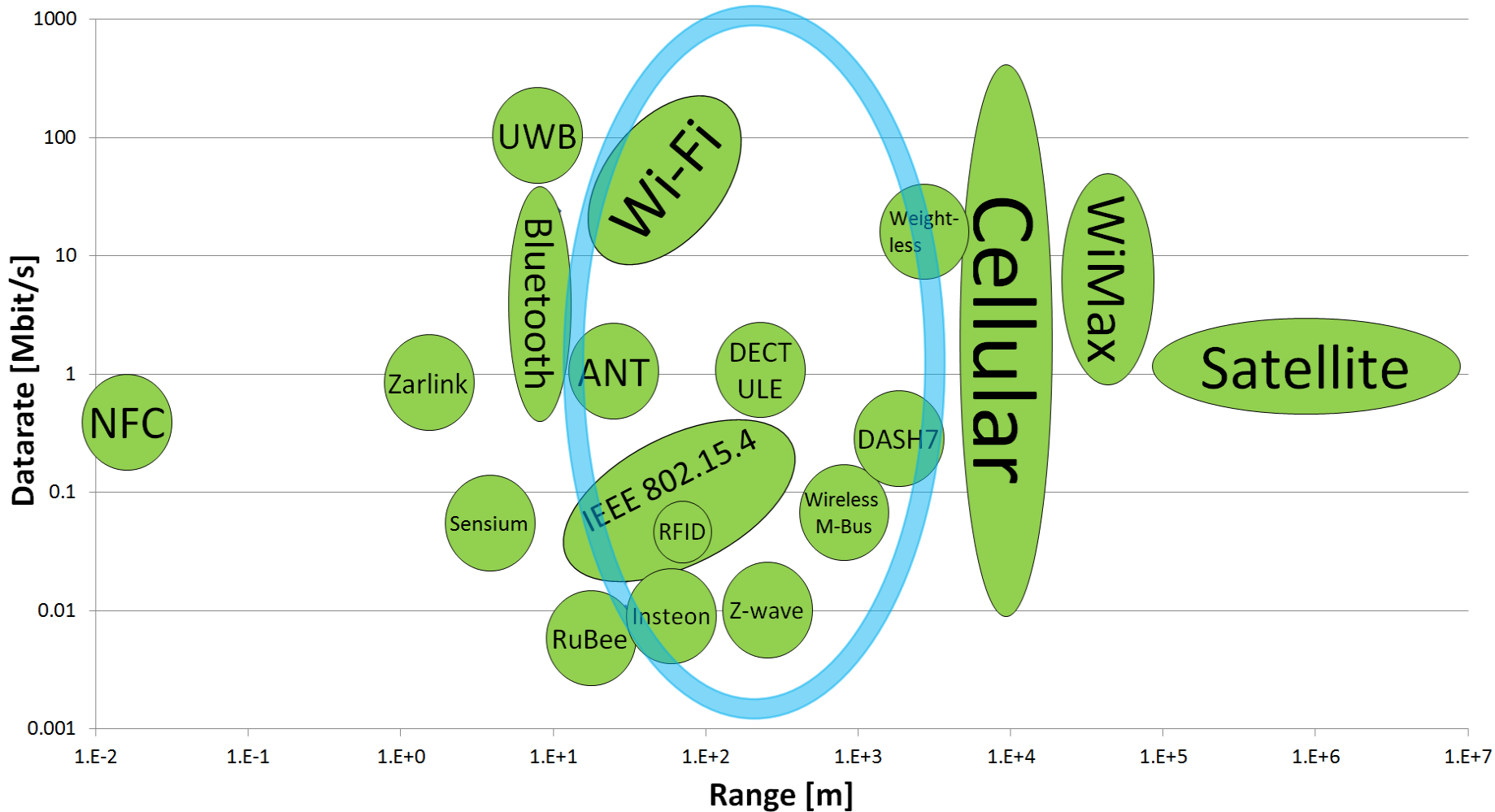
- Bigger buildings
  - Wider coverage
- Thicker and/or more walls (metals)
- No line of sight
- More money to spend

# Smart Factory Communication Requirements

- Long range or mesh topology support
- Convergence of different subnetworks



# Smart Factory Wireless Technologies



# Smart Factory Wireless Technologies

WiFi

DECT-ULE

Wireless-M-Bus

IEEE802.15.4

Z-wave

DASH7

RFID



# Big range vs Mesh topology

## Big range

- IEEE 802.11n: 100m
- Wireless M-Bus: 1000m
- DECT ULE: 300m
- DASH7: 2000m
- RFID: 100m

## Mesh topology

- Z-wave: 300m
- IEEE802.15.4: 250m

# Big range vs Mesh topology

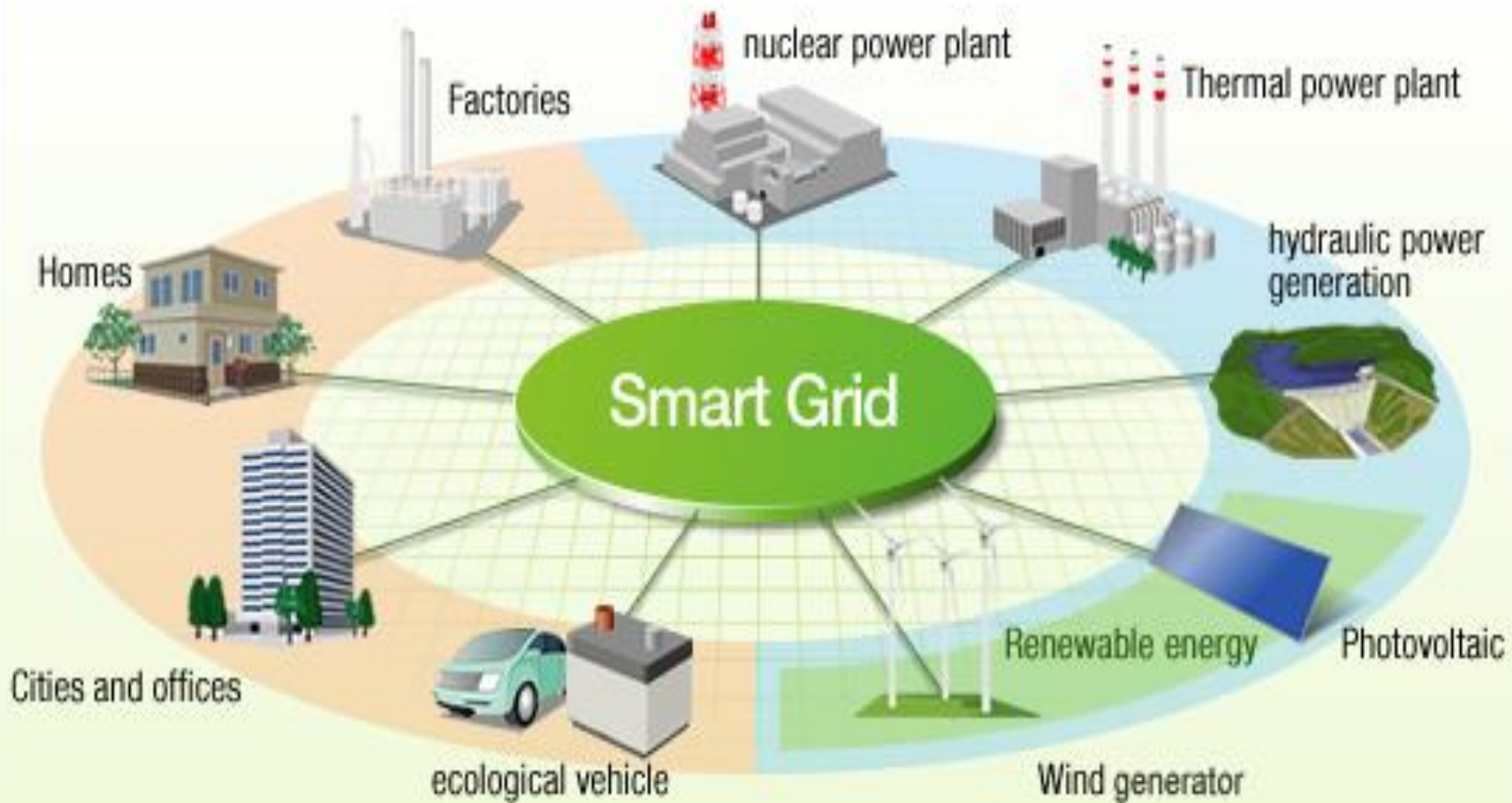
## Big range

- Operates at 2.4 GHz
- Operates at 868 MHz
- Operates at 1.9 GHz
- Operates at 433.92 MHz
- Access control, Identification

## Mesh topology

- «Vendor-locking»
- IEEE802.15.4: 250m

# Smart Grid



# Logistics



- Some specific applications
  - Quality of Shipment Conditions
  - Item Location
  - Storage Incompatibility Detection
  - Fleet Tracking

# Smart Grid & Logistics Characteristics

## Smart Grid

- Centralized two-way communication (tree)
- Wide coverage
- Hourly peaks

## Logistics

- Mobile → battery powered
- «Off-the-grid» environments
- Huge Variety

# Smart Grid & Logistics Communication Requirements

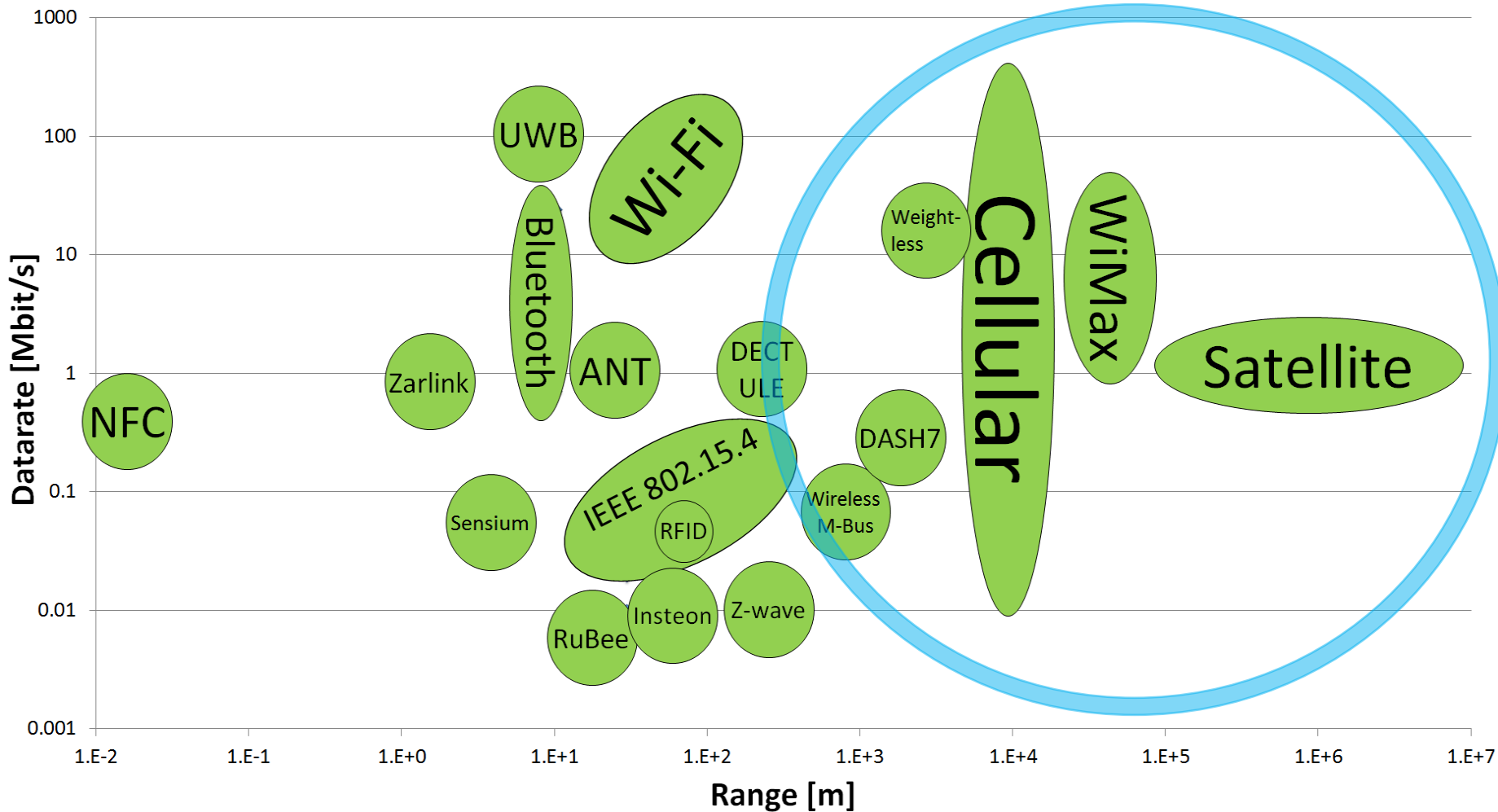
## Smart Grid

- Long range
- Short transfer latency  
(within a few ms)
- Scalable
- Interoperable

## Logistics

- Long range
- Scalable
- Interoperable

# Smart Grid & Logistics Wireless Technologies



# Smart Grid & Logistics Wireless Technologies

Cellular WiMax  
Wireless-M-Bus  
Weightless  
Satellite DASH7



# Smart Grid & Logistics Wireless Technologies

SMS

Data packets

Cellular WiMax

Indoor Environments  
Neighborhood Aggregator

Low reception Environments

Indoor Environments  
Neighborhood Aggregator

«Off-the grid»  
Environments

Satellite

# Weightless



# White Space Spectrum

The 402 MHz of broadcast TV spectrum resides between 54–806 MHz. Up to 67 broadcast channels (channels 2–69) are possible, but only a fraction are actually in use.

The 80-MHz bandwidth of the congested 2.4-GHz spectrum is shared by millions of Wi-Fi and Bluetooth devices, cordless and satellite phones, microwave ovens, etc.

Also used for wireless communications, but is limited by shorter range.



## White Spaces

The White Spaces are the under-used portions of the 186 MHz of broadcast TV bandwidth between 512–698 MHz (channels 21–51).

Most wireless communications occur below 3.1 GHz where signal range and operating characteristics are best suited to these applications.

The White Spaces add enough bandwidth to the congested 2.4-GHz spectrum to continue to revolutionize wireless communications in the U.S.

# Conclusion

