

IRN

Vehicular Communications – Part II

Introduction to Radio Networks

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Office Hours:
Monday 4 – 6 pm
(upon prior agreement via email)

*Slides are provided
as supporting tool,
they are not a textbook!*

Outline

1. Radio Networks
2. Radio Communication Standards
3. Trends
4. Syllabus
5. Network Architectures for Vehicular Communications

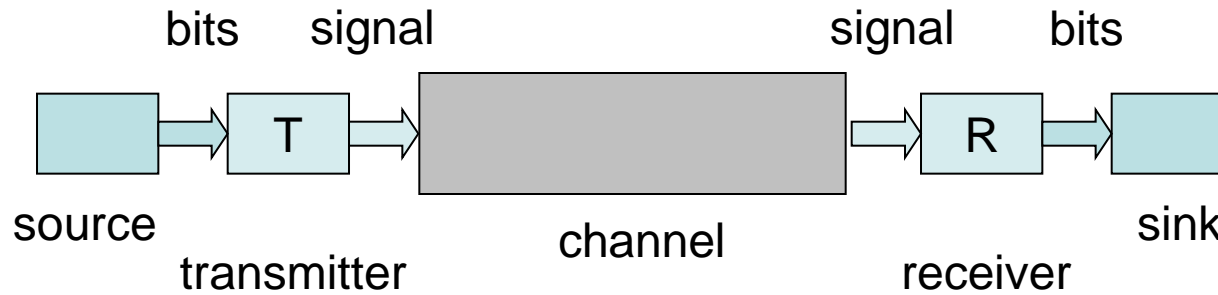
This lecture block will introduce the basic concepts related to radio networks and will provide information on the course syllabus.

An introduction to vehicular networks seen from the network viewpoint, is also given.

1. Radio Networks (RN)

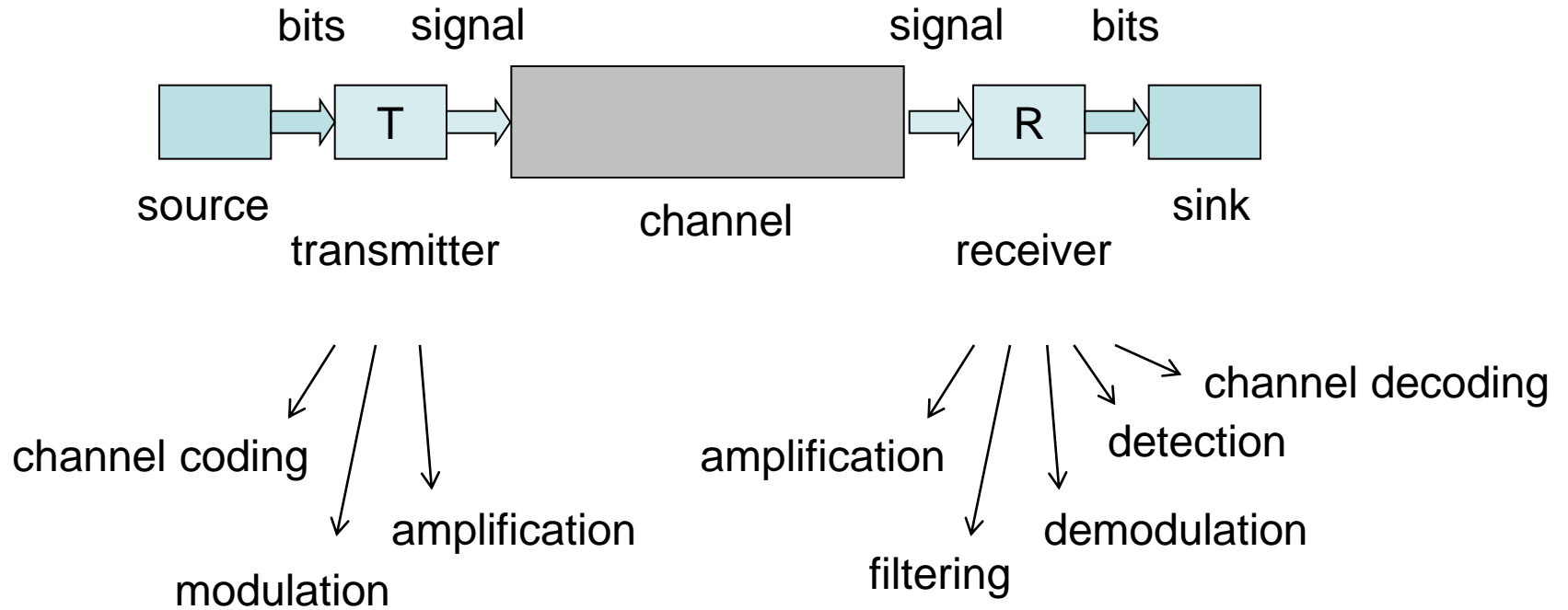
Digital Communications

Link Level



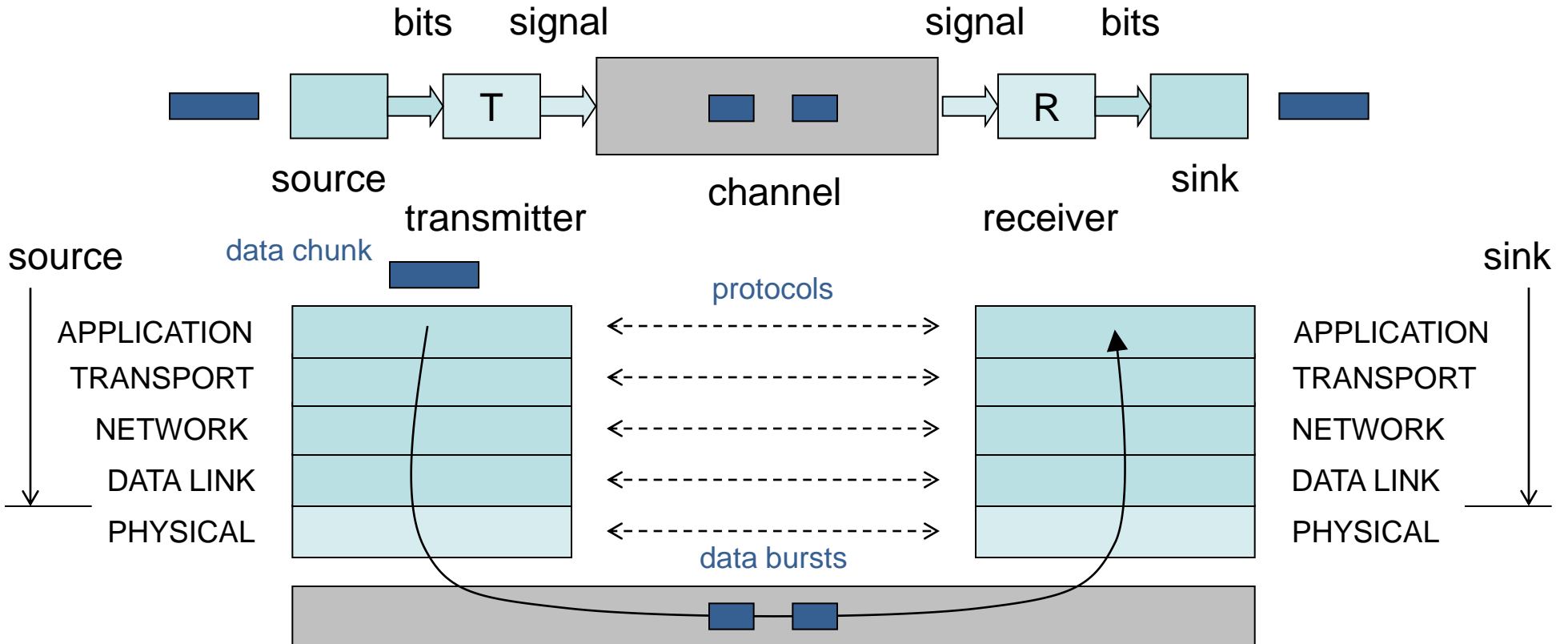
Digital Communications

Link Level



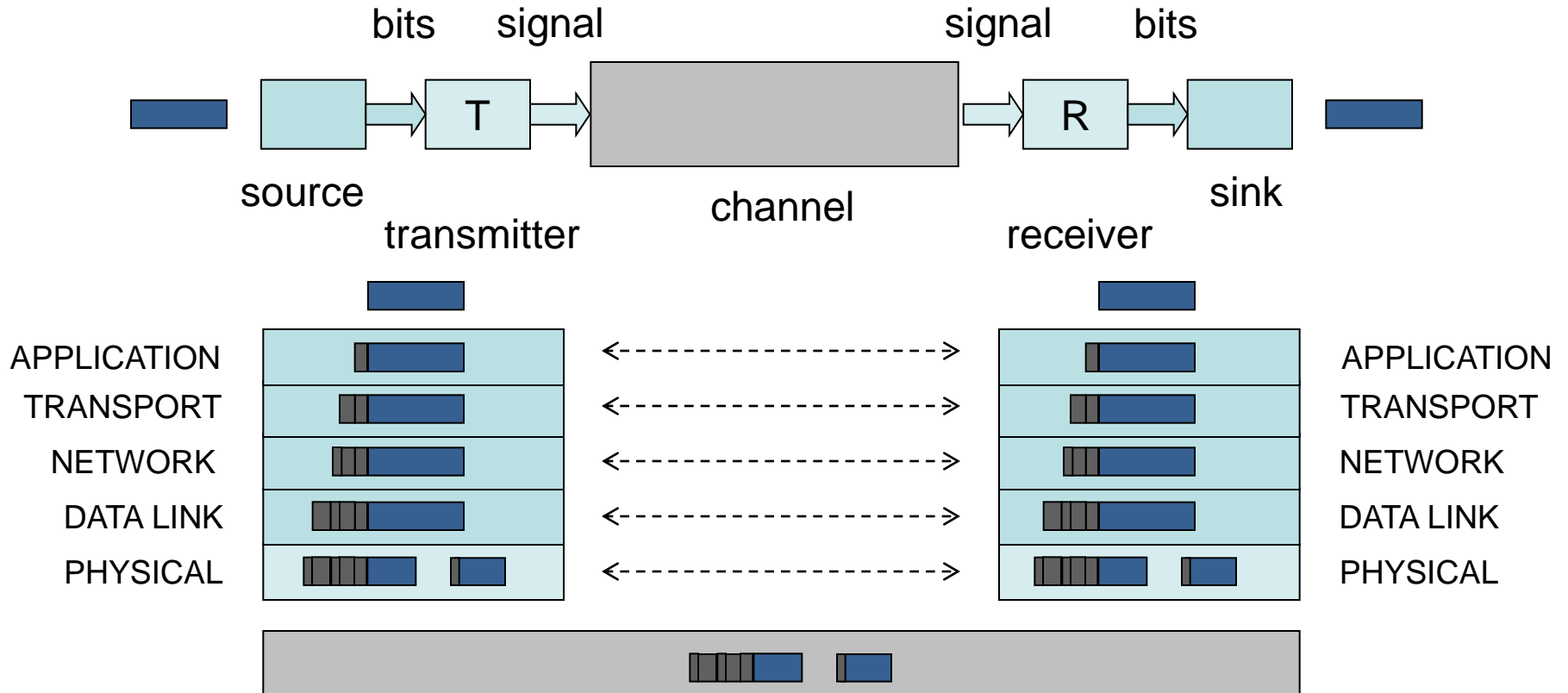
Digital Communications

Link Level



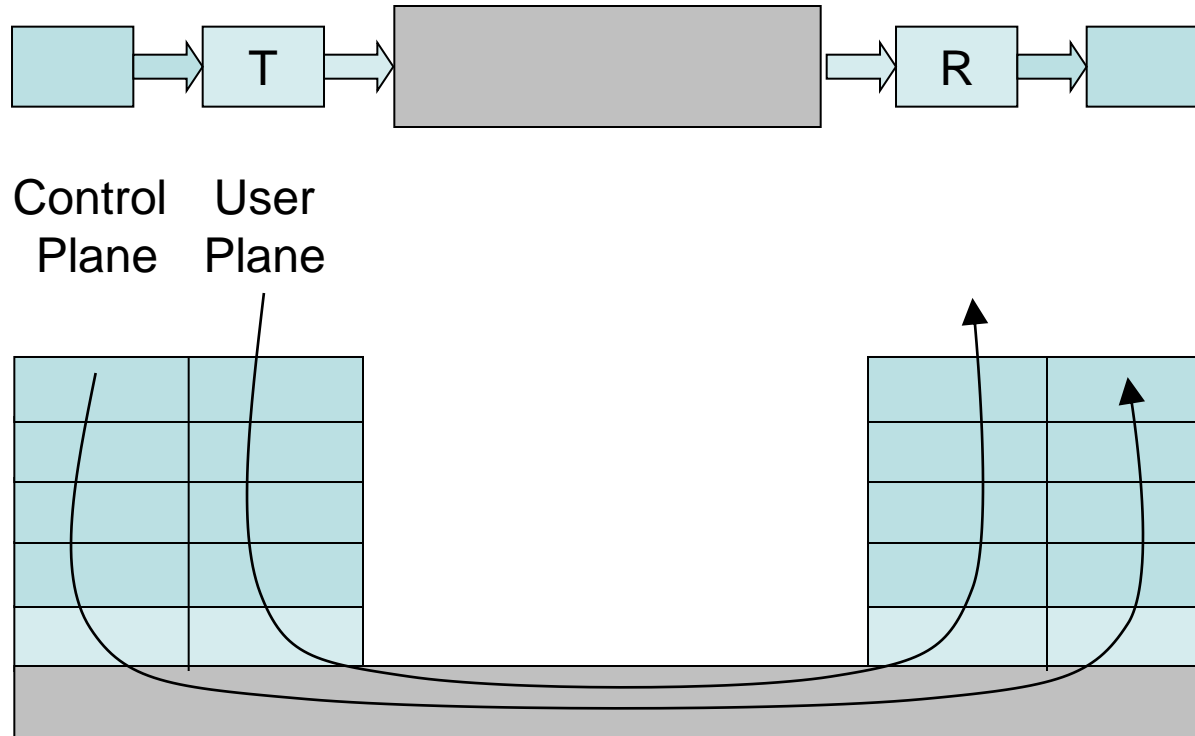
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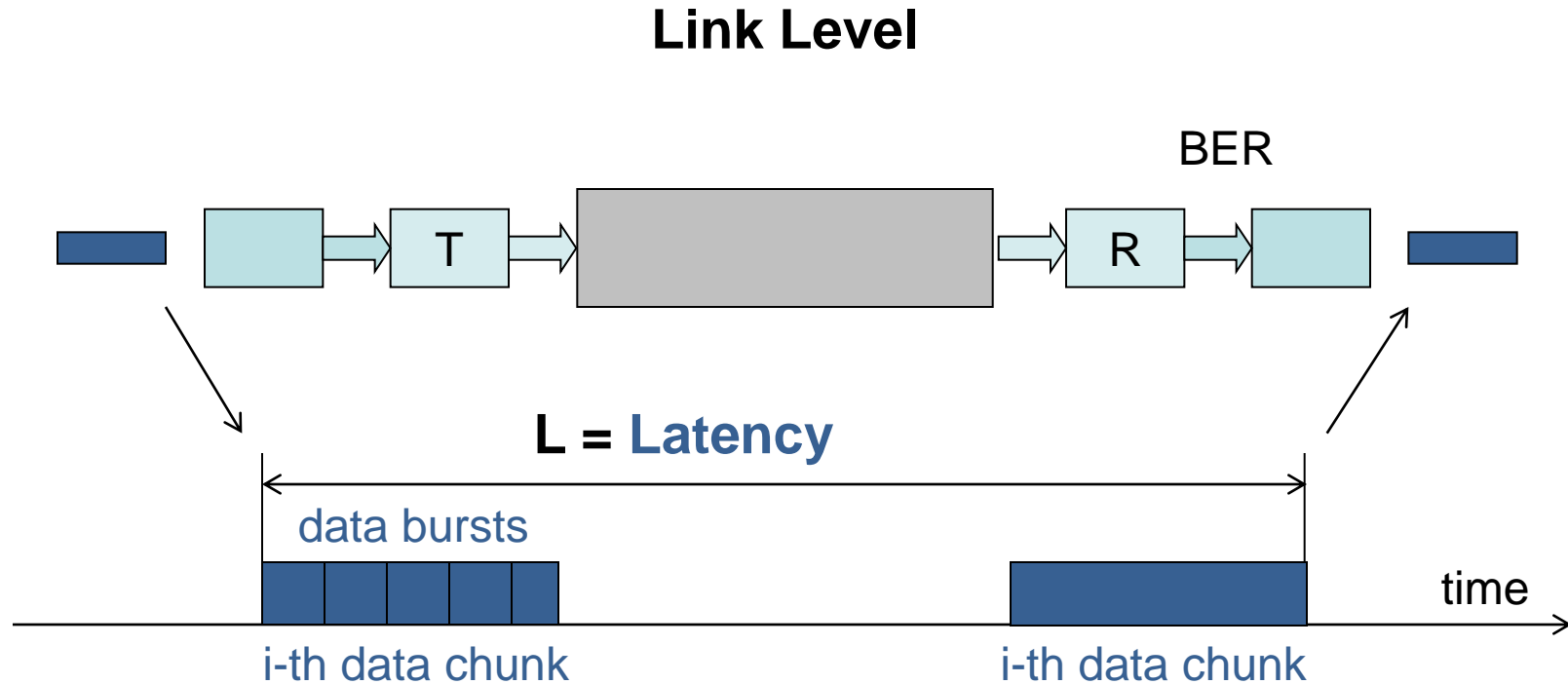
Digital Communications

Link Level



Digital Communications

Requirements on the User Plane

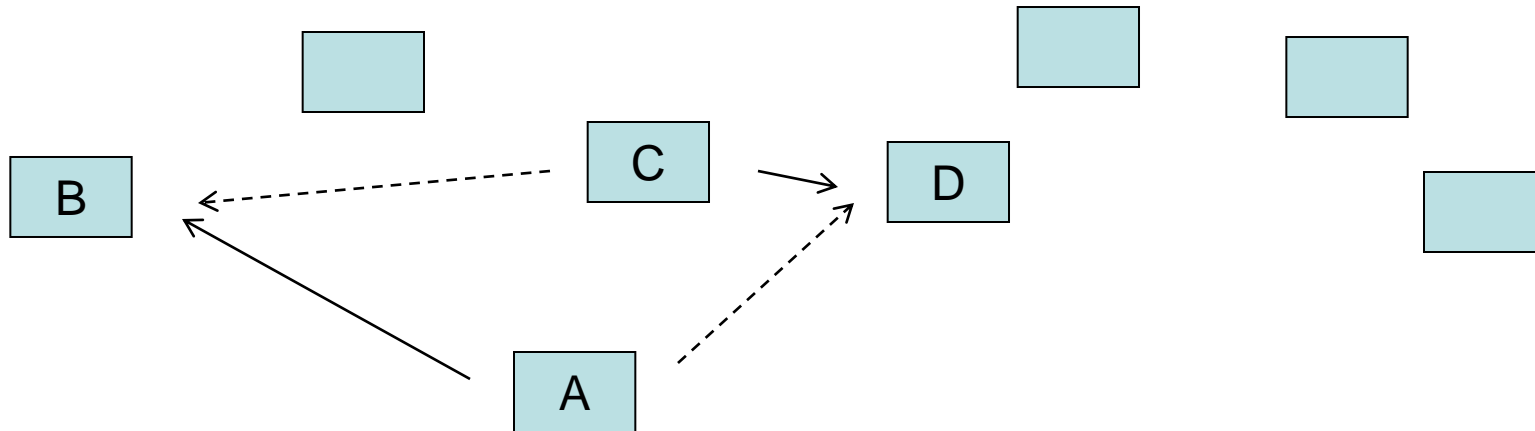


U = User Throughput = Number of information bits per second received

BER = Bit Error Rate = Percentage of erroneous bits

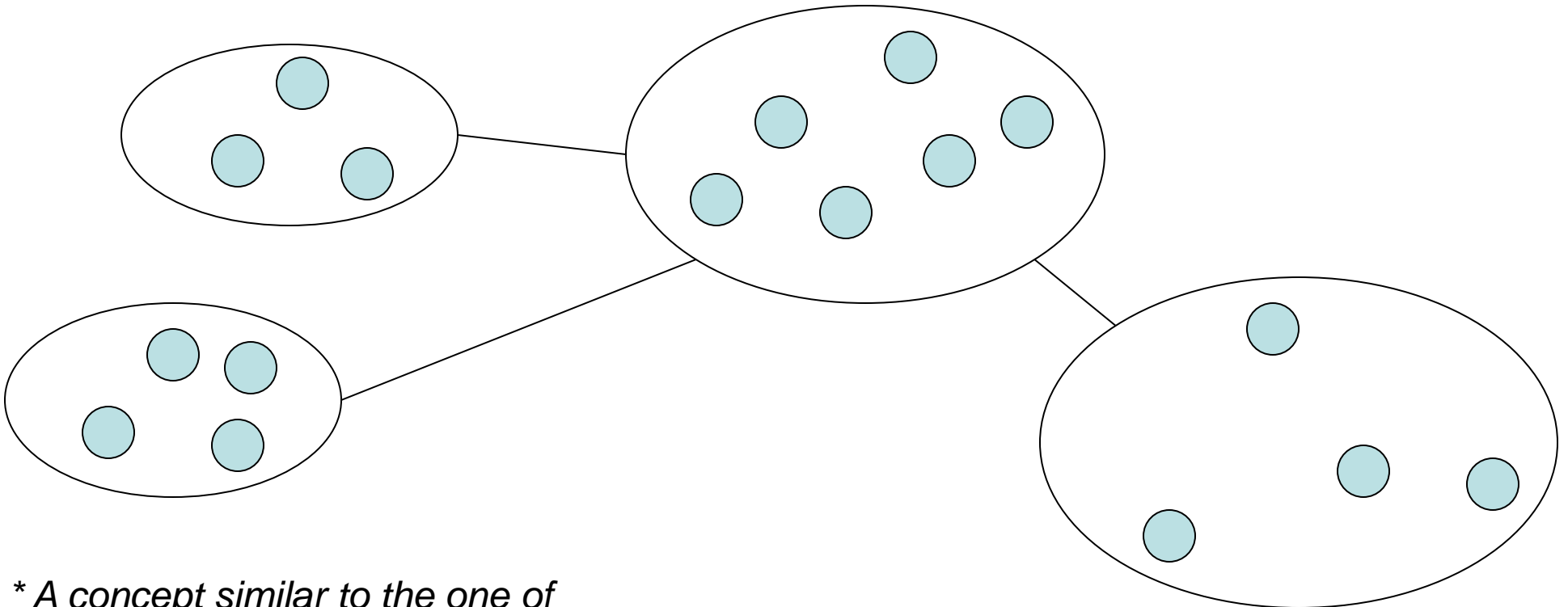
Radio Networks

Network Level



Radio Networks

RN = *Networks of Communication Networks made of *Nodes* connected through *Radio* links.**

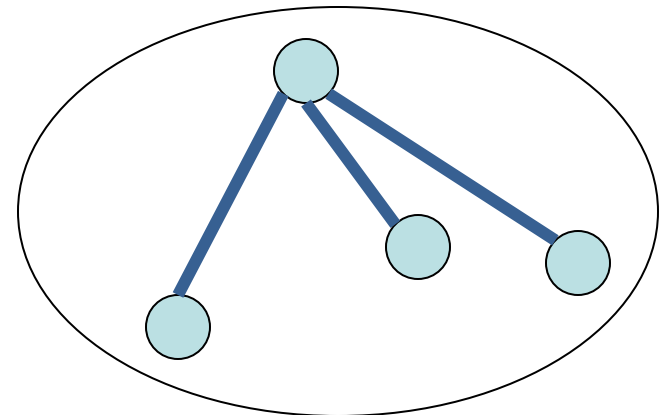


** A concept similar to the one of "Systems of Systems" used in system theory.*

Radio Networks

RN = *Networks of Communication Networks* made of *Nodes* connected through *Radio* links.

A *Communication Network* (CN) is a set of interconnected entities* sharing the same communication protocols.



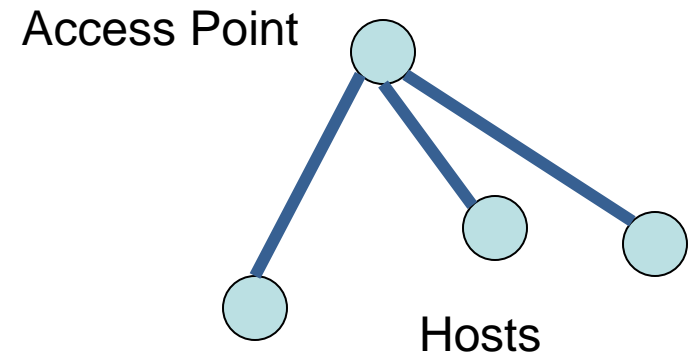
* The word “entity” here (synonym of “node”) refers to either human-oriented devices (smartphones, laptops, etc.) or unmanned things (objects, sensors, robots, drones, etc.)

Radio Networks

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e.g.

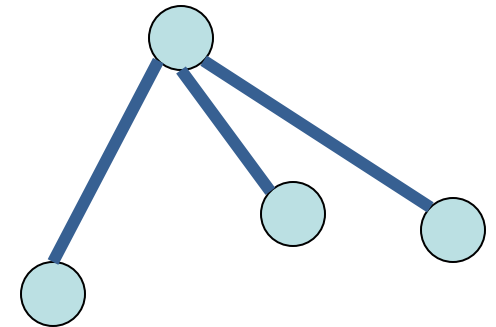


Radio Networks

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***Protocols* are set of rules coordinating the exchange of data.**

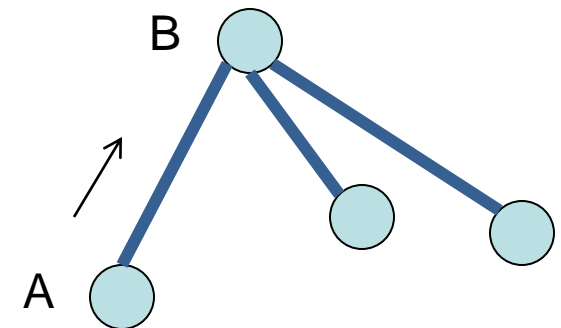
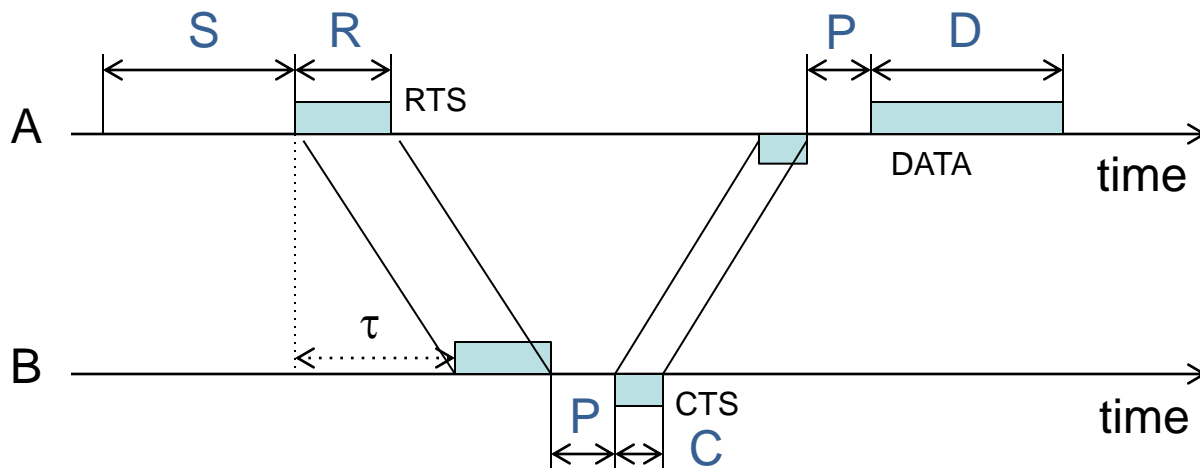


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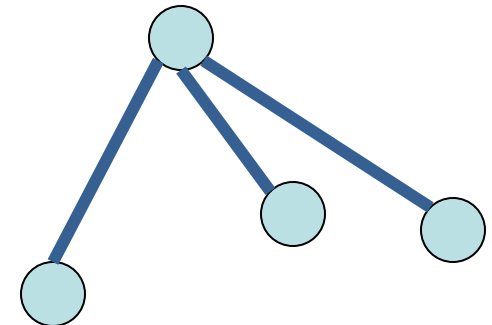
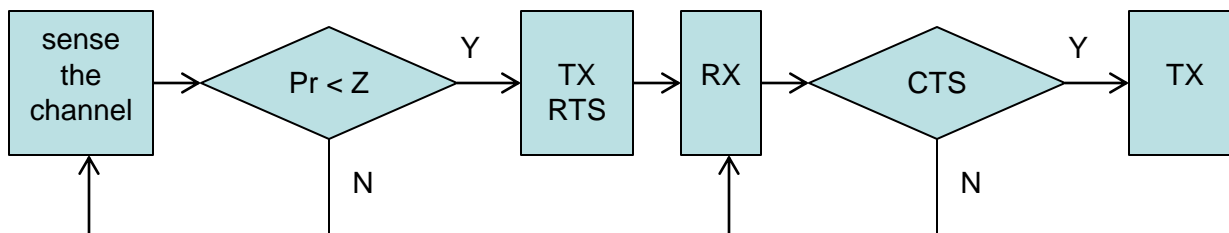
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Nodes implement **Algorithms** to take decisions regarding data transmission and reception.



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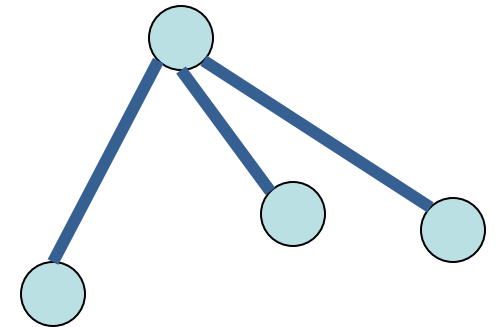
A *Communication Network* (CN) is a set of interconnected entities sharing the same communication protocols.

***Protocols* are set of rules coordinating the exchange of data.**

Nodes implement *Algorithms* to take decisions regarding data transmission and reception.

Radio *standards* include the precise description of *protocols* to ensure *interoperability* among devices of different vendors.

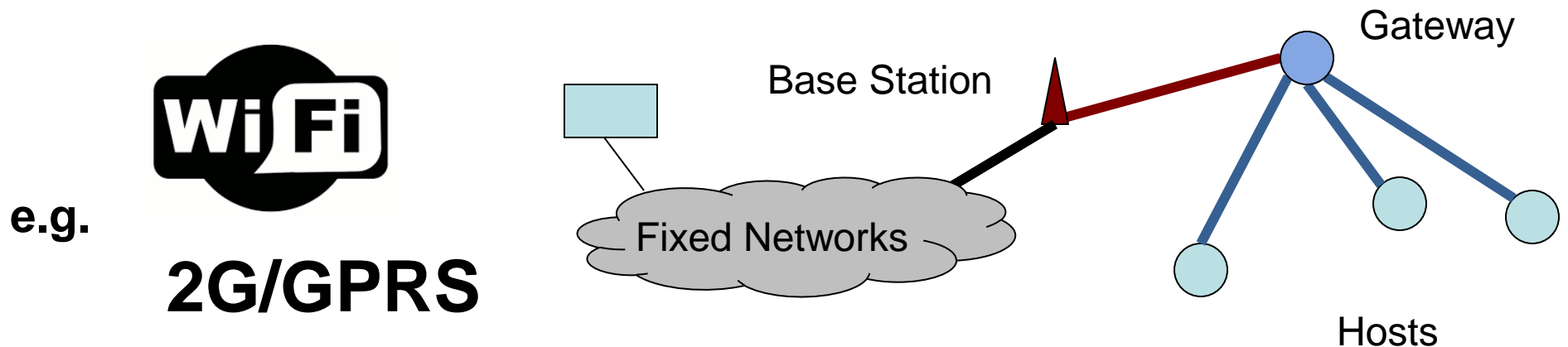
Sometimes, *algorithms* on the opposite are left to the manufacturer.



Radio Networks

RN = Networks of Communication Networks made of **Nodes** connected through **Radio** links.

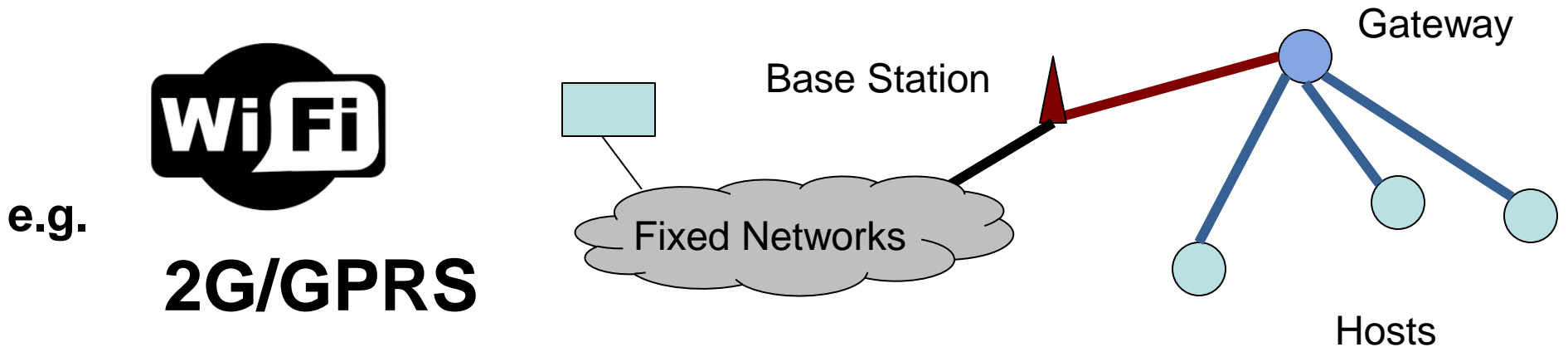
A **Network of CNs** is a set of interconnected CNs having separate protocols and linked through **interworking units**.



Radio Networks

RN = Networks of Communication Networks made of **Nodes** connected through **Radio** links.

A **Network of CNs** is a set of interconnected CNs having separate protocols and linked through **interworking units**. Such Network is also called a **Network Architecture**.

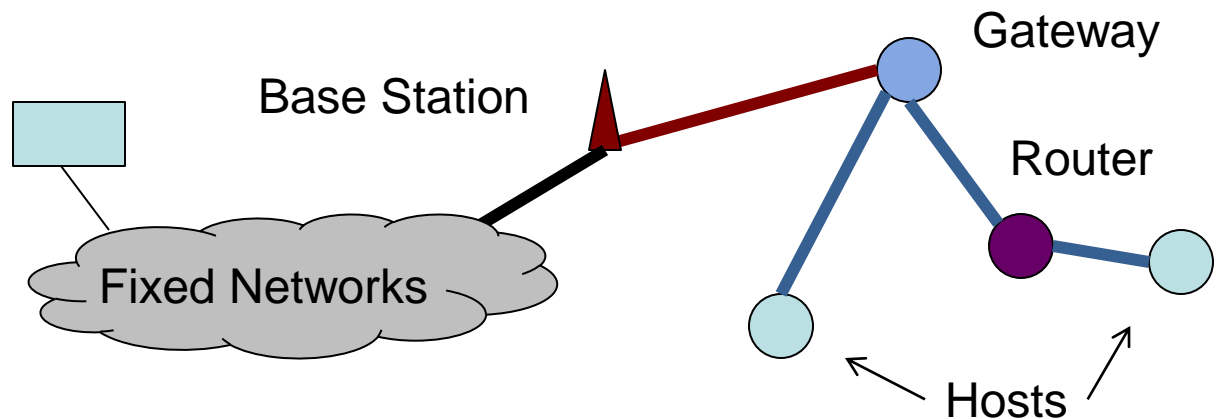


Radio Networks

RN = Networks of Communication Networks made of Nodes connected through Radio links.

Nodes can play different roles:
hosts (information *prosumers*), routers, gateways, base stations, etc.

e.g.
WiFi
2G/GPRS

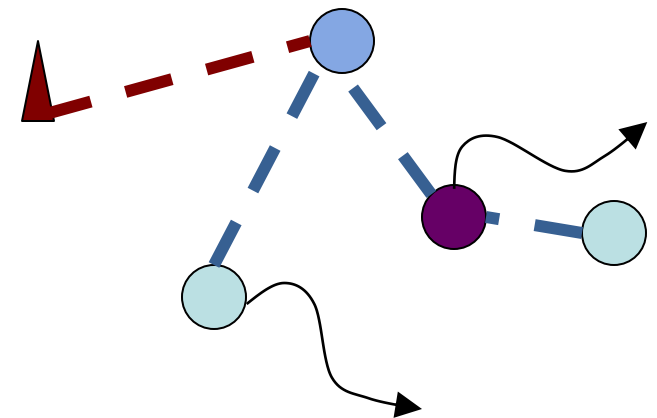


Radio Networks

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***Nodes* can play different roles:
information prosumers, routers, gateways, etc.**

**Nodes in a radio network exchange data through
Radio Waves. They can be *mobile*.**



Radio Networks

RN = *Networks of Communication Networks* made of *Nodes* connected through *Radio* links.

Why *Radio, not *Wireless*?**

***Wireless* just says “with no wires”, neglecting the essence of the radio channel.**

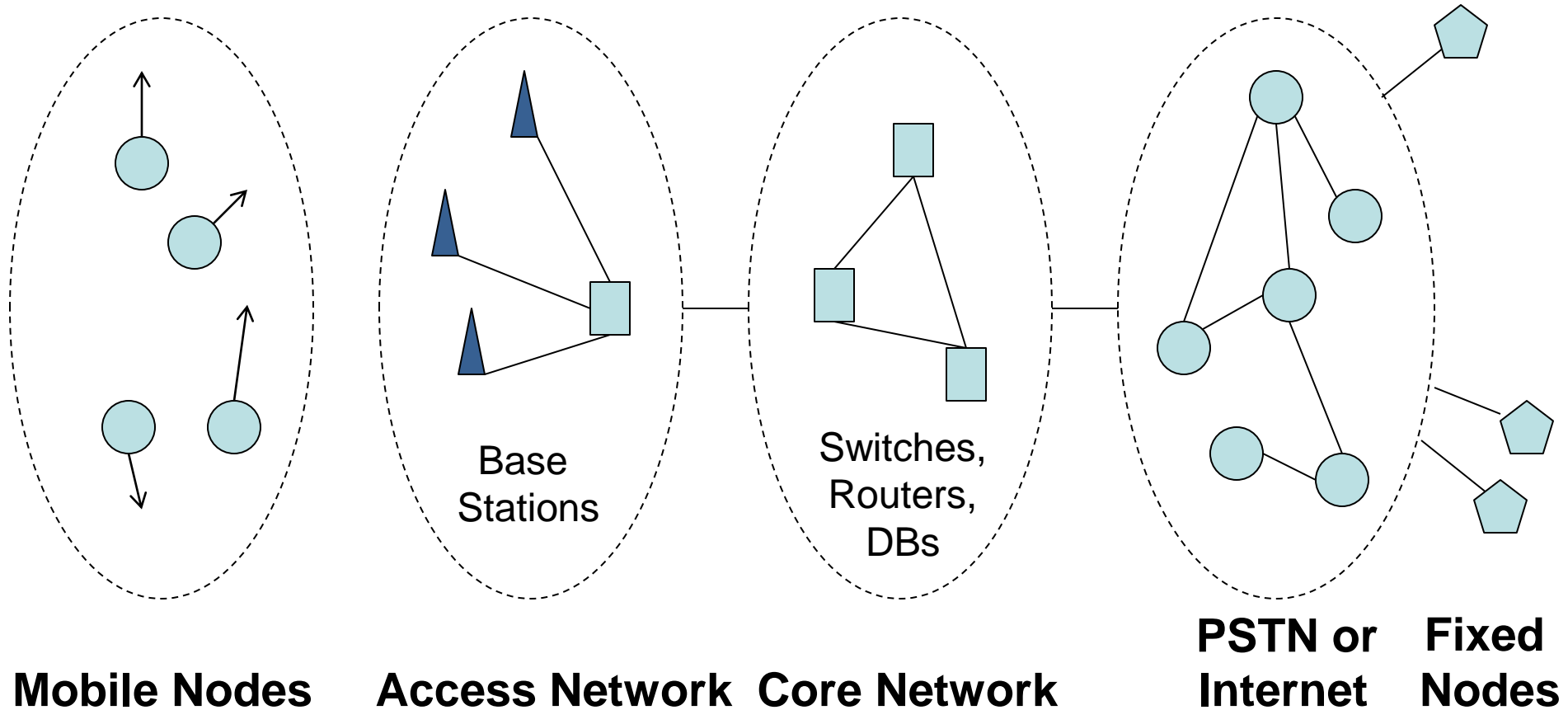
***Radio* reflects the relevance of the transmission medium on the network ability to exchange data.**

The word stresses the implications of the physical on the digital world.

* *Etymology of Radio: Radius [lat] = ray of light*

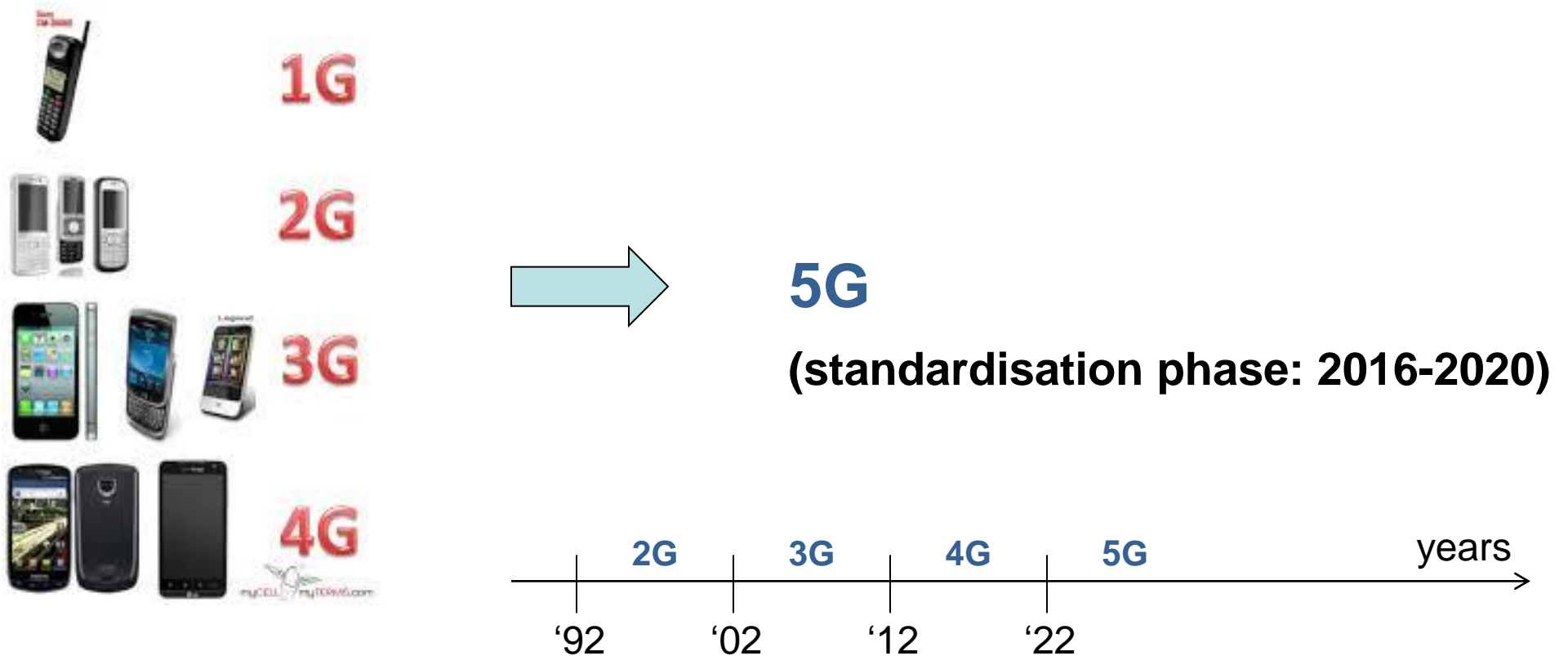
Mobile Radio Networks

Radio Networks permitting large scale (geographical) node *Mobility*.



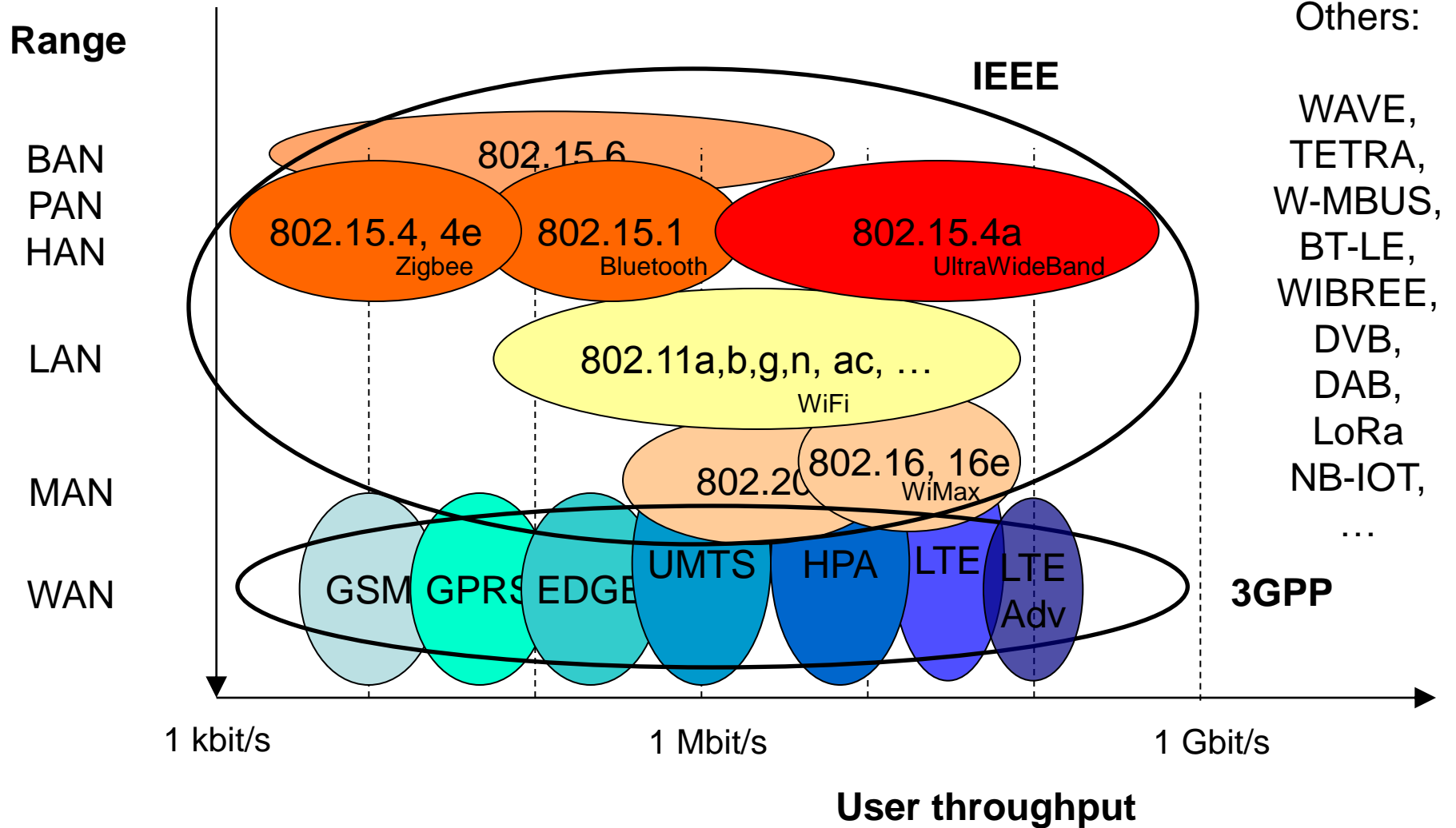
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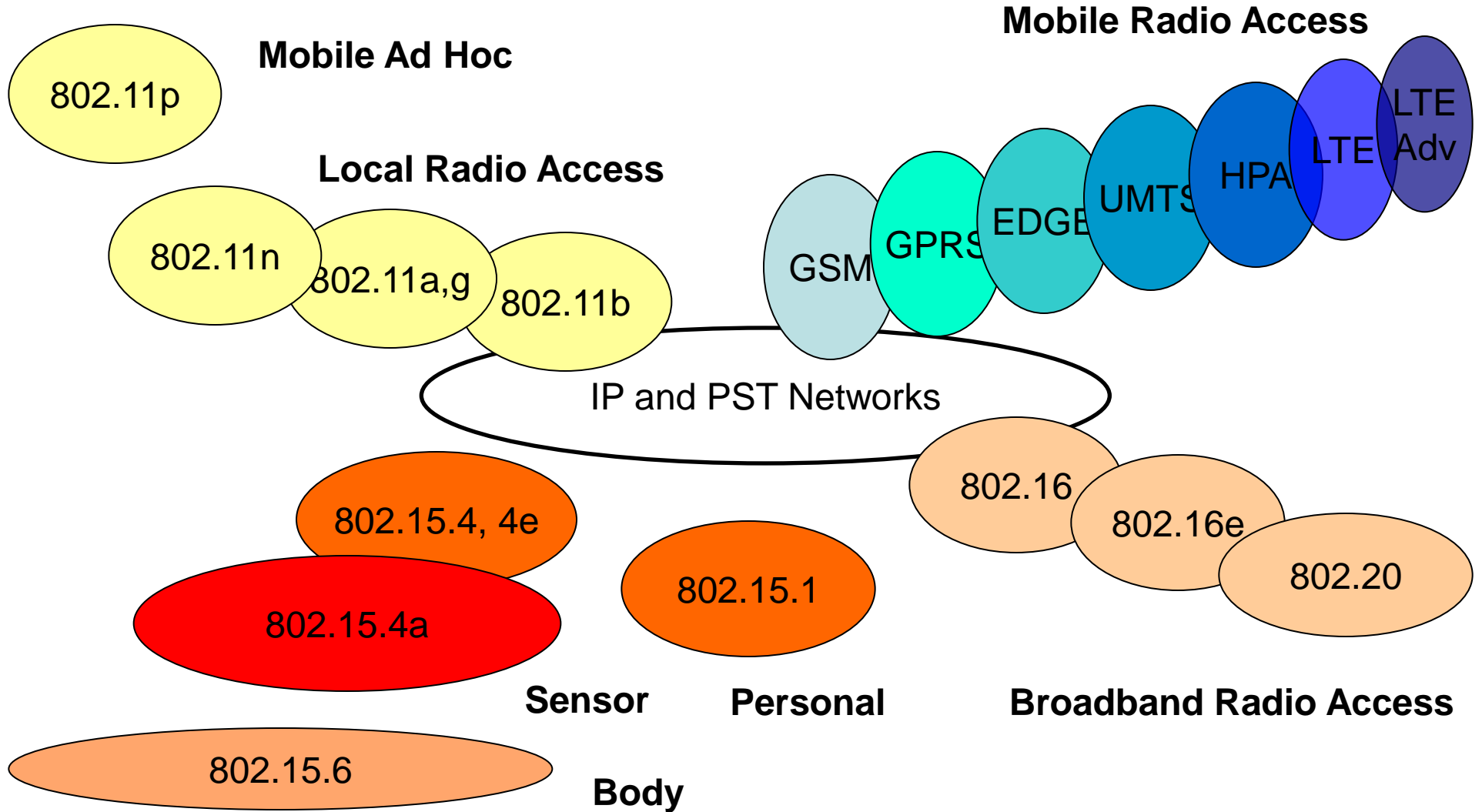


2. Radio Communication Standards

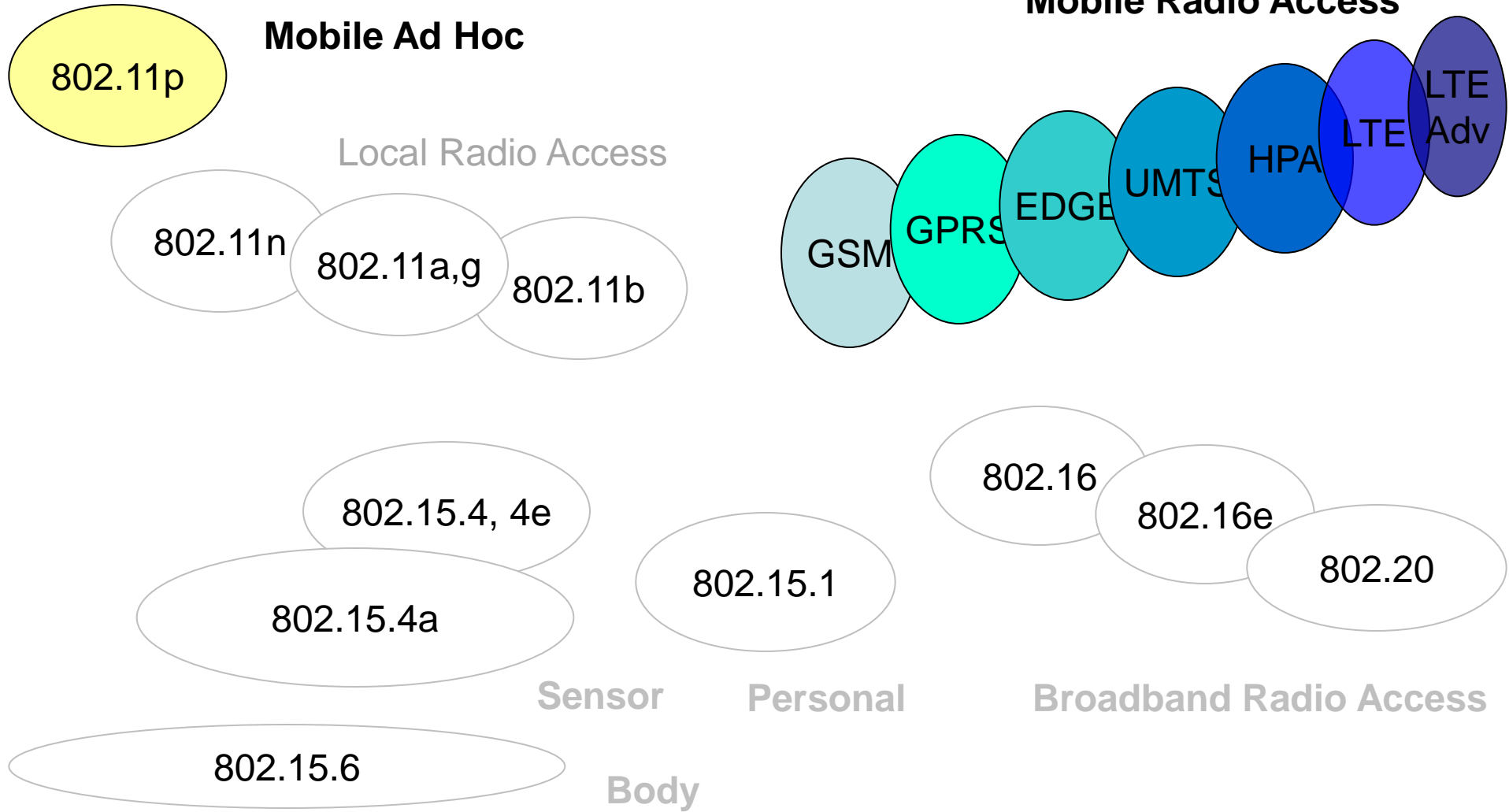
Radio Communication Standards



Radio Communication Standards

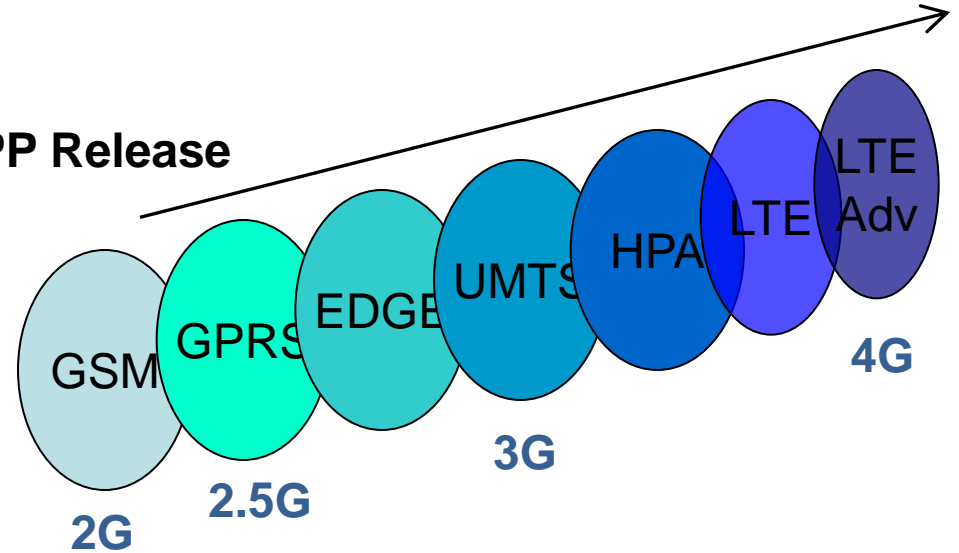


Radio Communication Standards



Radio Communication Standards

3GPP Release



years	2G	3G	4G	5G
Bands [MHz]	900, 1800	2000	800, 2000, 2600	700, 3600, 26000
Bandwidth	200 KHz	5 MHz	5-20 MHz	100+ MHz
Waveform	GMSK	DSSS	OFDM	?
Bit Rates	271 Kbit/s	2 Mbit/s	100 Mbit/s	1 Gbit/s ?
Latency [msec]	300	100	10	1

Inquiry Based Session

When proprietary solutions are attractive?

How do you think a standardisation body (like e.g. 3GPP) works?

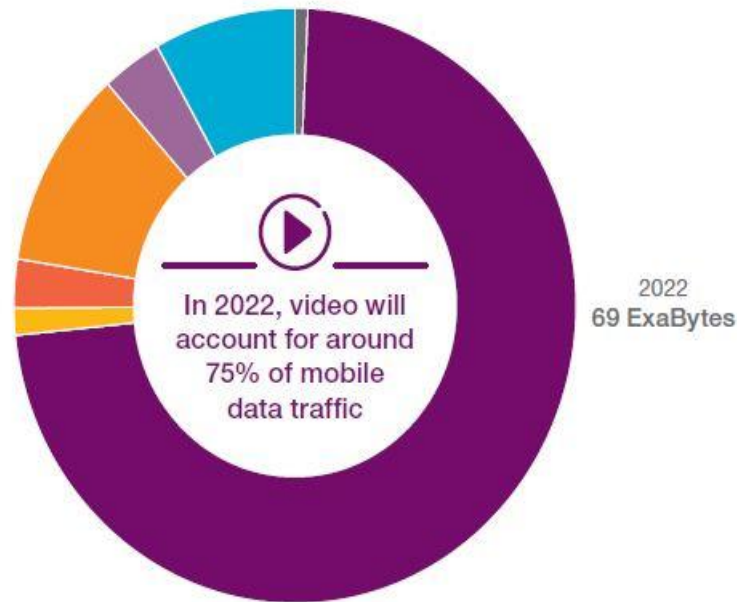
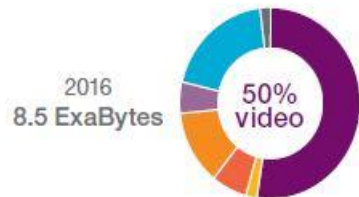
3. Trends

Trends: Data

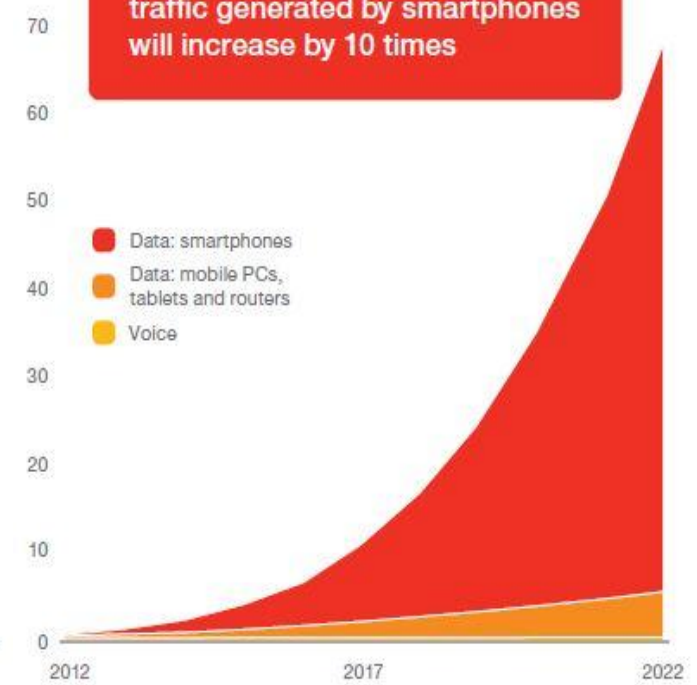
MRN: Data

Mobile traffic by application category per month (ExaBytes)

- Video
- Audio
- Web browsing
- Social networking
- Software download
- Other
- File sharing



Between 2016 and 2022, the traffic generated by smartphones will increase by 10 times

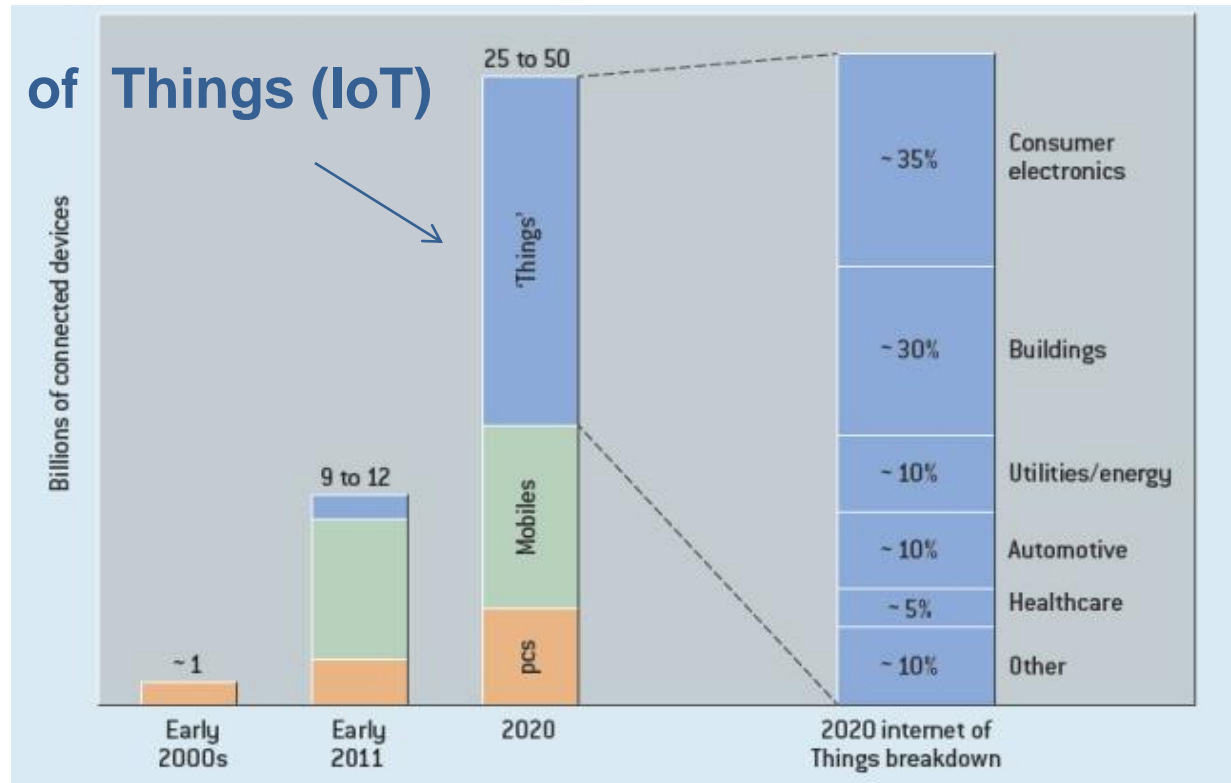


¹ Video is likely to form a major part of file sharing traffic in addition to the identified application type 'video'
² Ericsson ConsumerLab, TV and Media (2016)

Trends: Devices

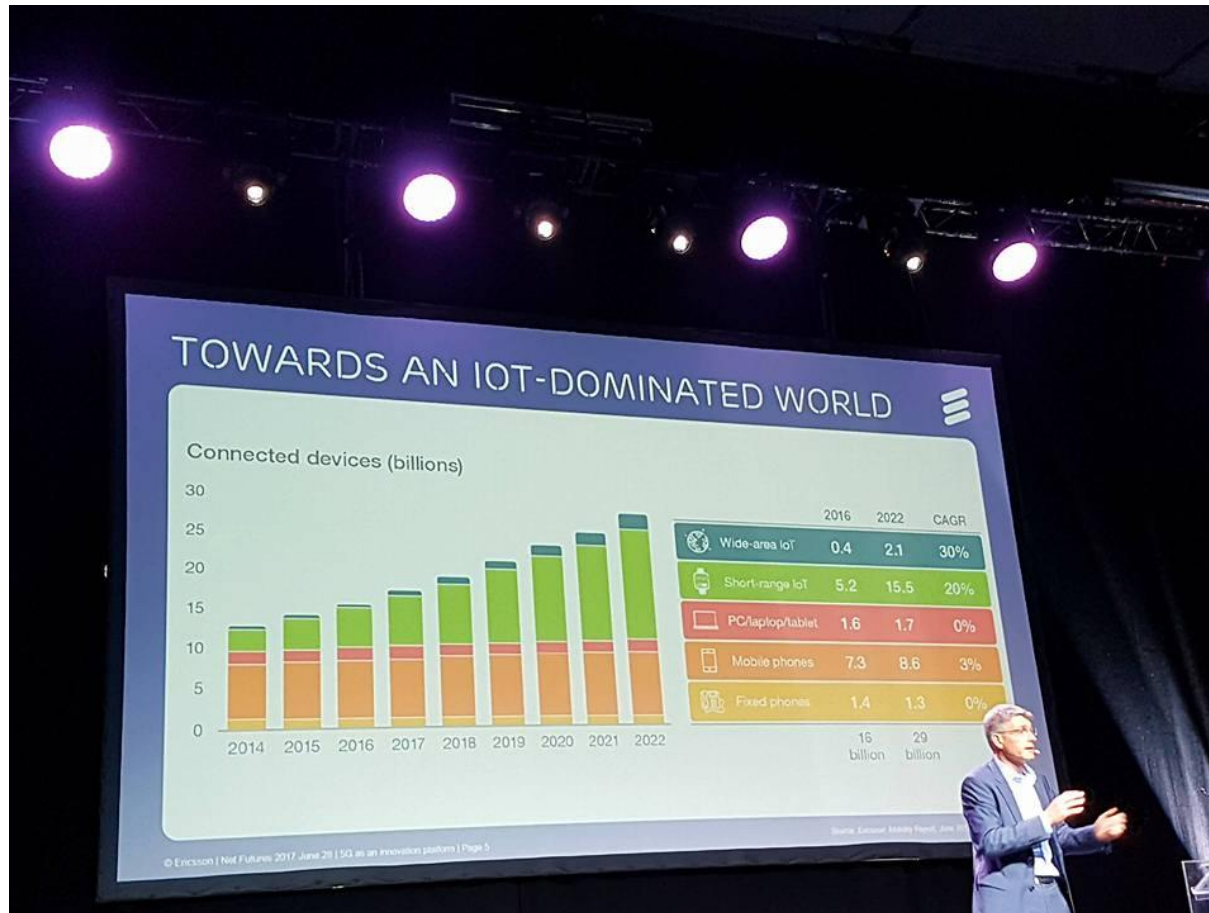
MRN: Number and Type of Connected Devices

Internet of Things (IoT)



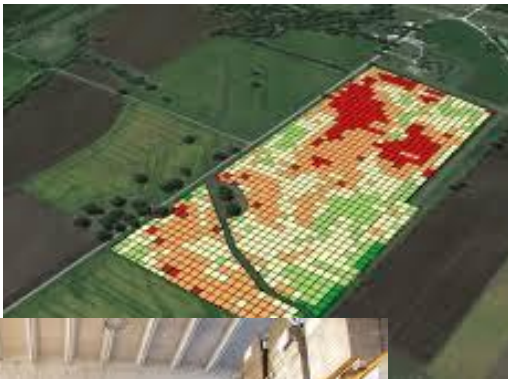
Trends: Devices

MRN: Number and Type of Connected Devices



Trends: IoT Applications

Smart Agriculture



Connected Cars



Animal Tracking



Smart Spaces

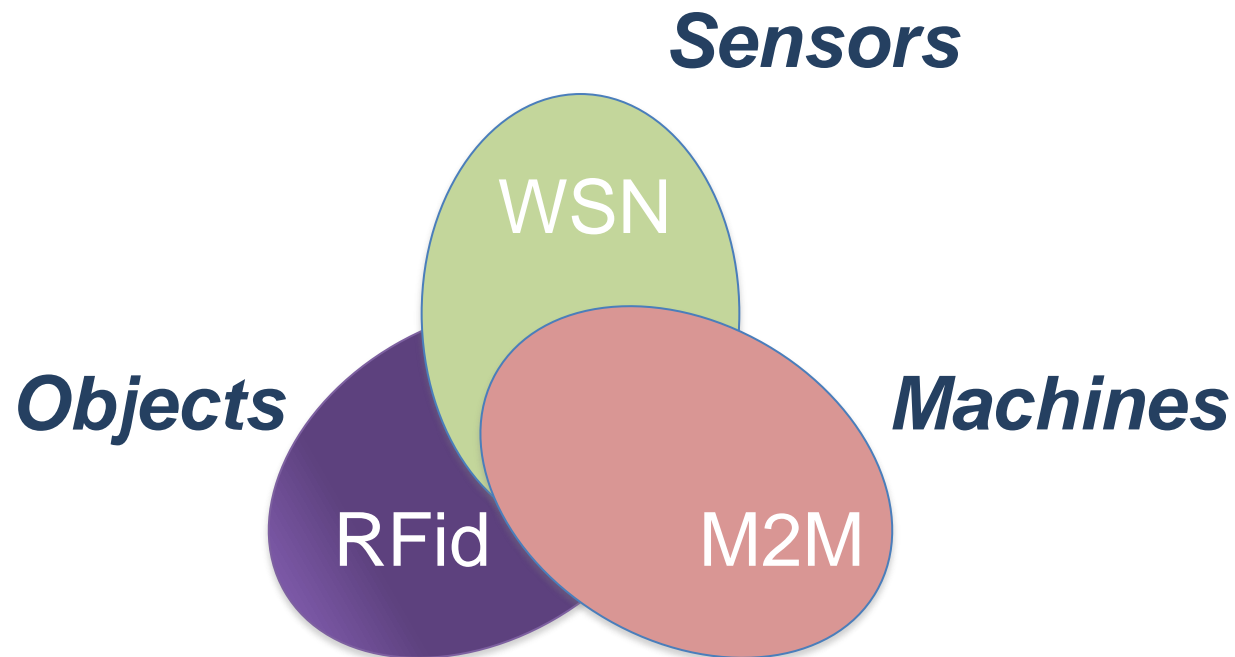


Smart Cities



Smart Buildings

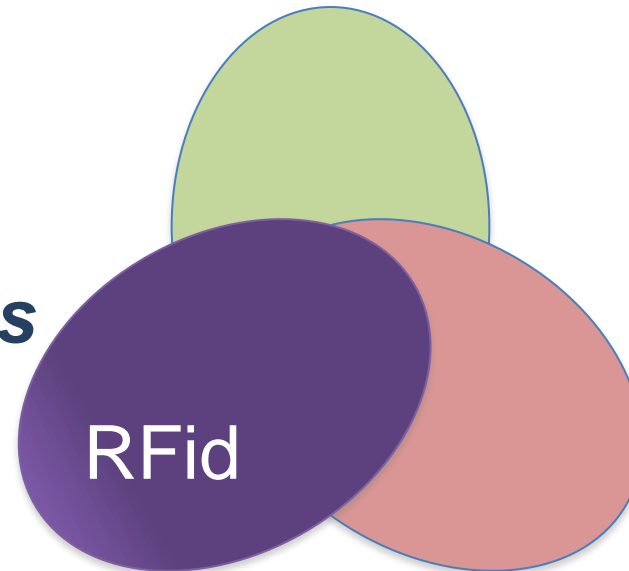
Trends: IoT



Trends: IoT

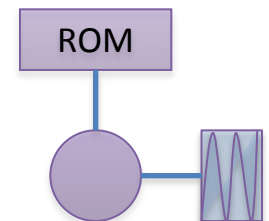


Objects



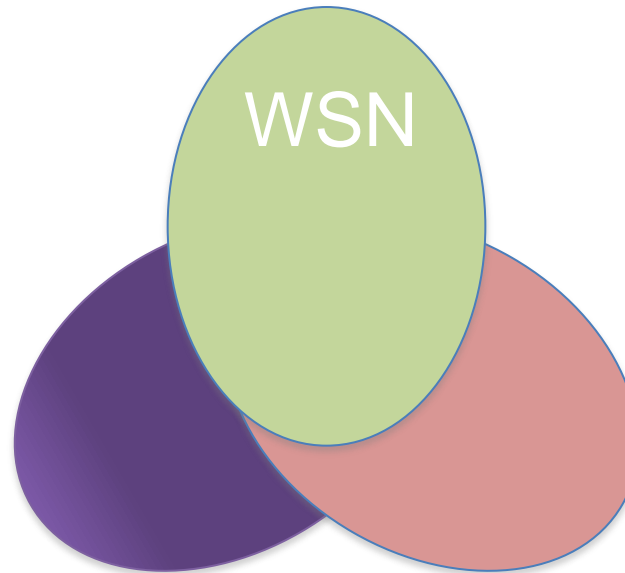
Objects equipped with RFid Tags:

- Identification
- Passive
- No computing capabilities



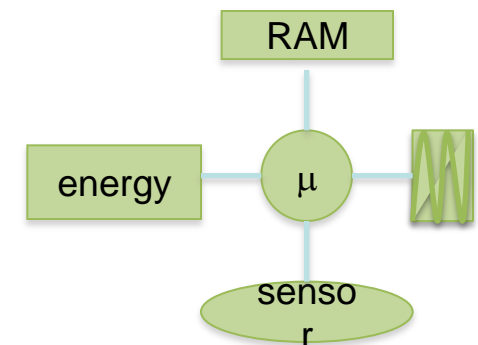
Trends: IoT

Sensors

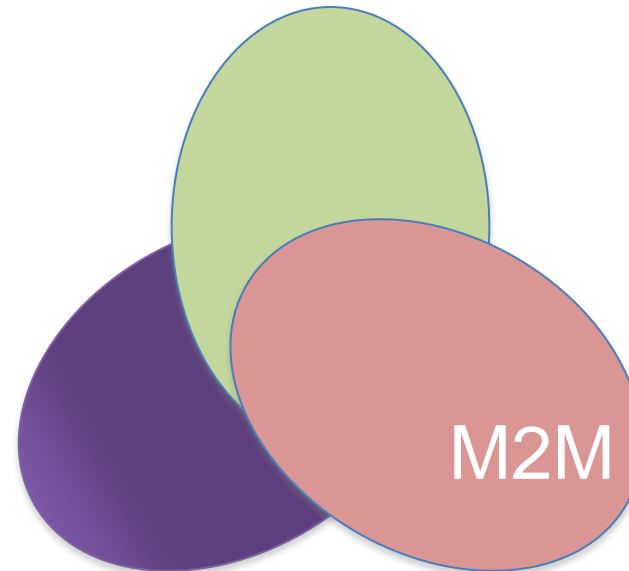


(Embedded) devices equipped with sensors:

- Sensing
- Battery or energy grid
- Some computing capabilities



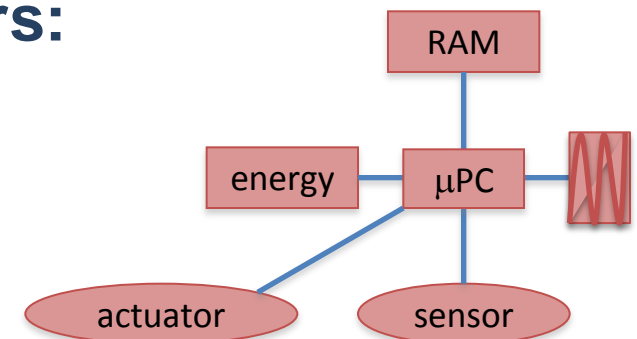
Trends: IoT



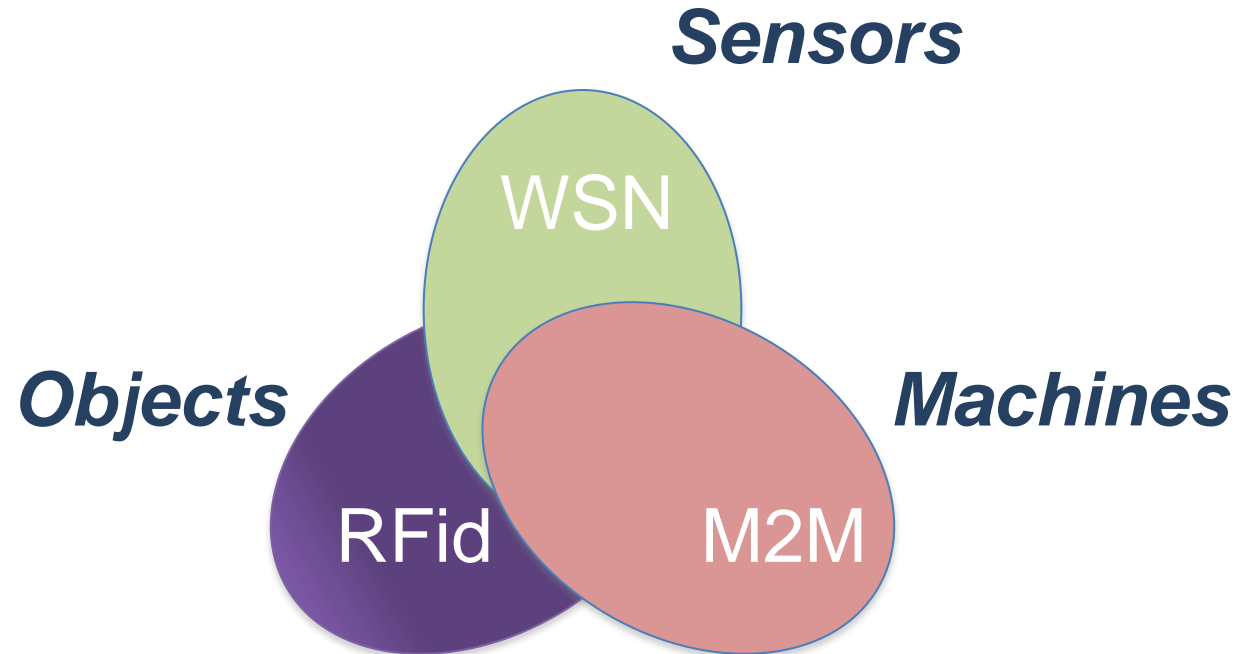
Machines

Machines equipped with sensors / actuators:

- Sensing & Actuation
- Industrial Control
- High computing capabilities

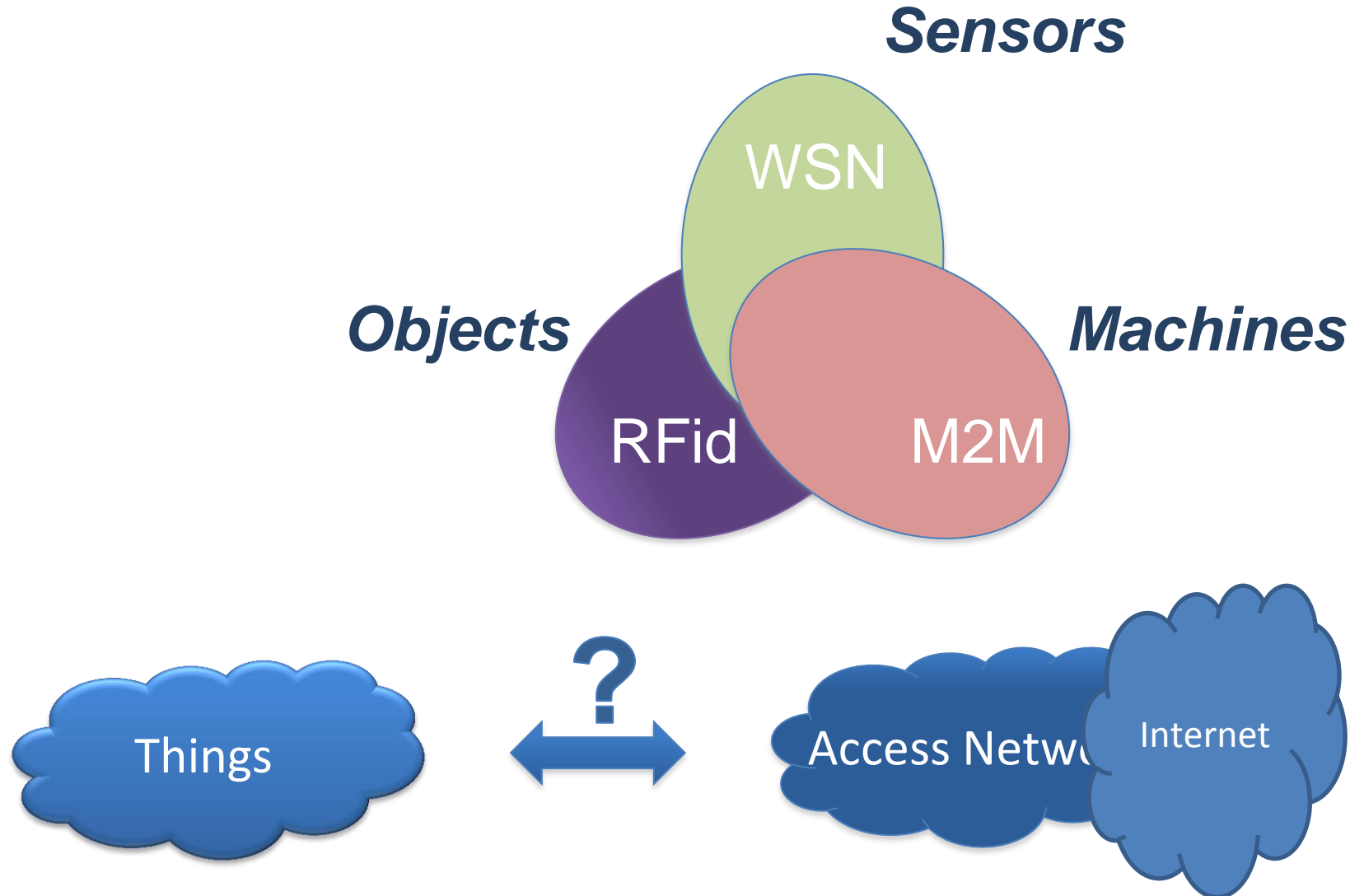


Trends: IoT



The IoT intends to connect to the Internet, wirelessly, *unmanned devices* of very different nature, complexity and capabilities.

Trends: IoT



4. Syllabus

The Course: Lecture Blocks (30 hours)

- IRN Introduction to Radio Networks**
 - TTN Transmission Techniques for Noise Limited Systems**
 - RCC Radio Channel Characterisation**
 - TTF Transmission Techniques for Fading Channels**
 - IMN Interference Management in Networks**
 - RRA Radio Resource Assignment**
 - RNV Radio Networks for Vehicular Communications**
-

The Course

Instructor:	Roberto Verdone	roberto.verdone@unibo.it *
Teaching Assistant:	n. a.	
Website:	www.robertoverdone.org → Teaching → Veh. Comm. PLEASE FILL THE FORM WITH YOUR CONTACTS BEFORE END OF THIS WEEK	
Teaching Material:	Handouts will be available as pdf files on website	
Exam:	Single step: one exercise + oral	
Additional Material:	Handwritten notes plus references to books Audio recording of lectures (one of you as contact point) Homework, further reading Self-assessment tools, etc. Books available in my office for daily use	

* Clear e-mails no longer than three lines, requiring answers that can be given in three lines.

The Course: Tips – secrets to succeed

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Take *notes* during the lectures!

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Take *notes* during the lectures!

Look for *details*; be precise.

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Engineers do not use adjectives and adverbs. They use *numbers*.

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Assess yourself through the *self-assessment tools* we will provide.

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Be *interactive* during the lectures!

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The slides provided are not a textbook!

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Use the audio records to complement

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Use the audio records to complement

Record any single sign made on the board

Appendix: just to check...

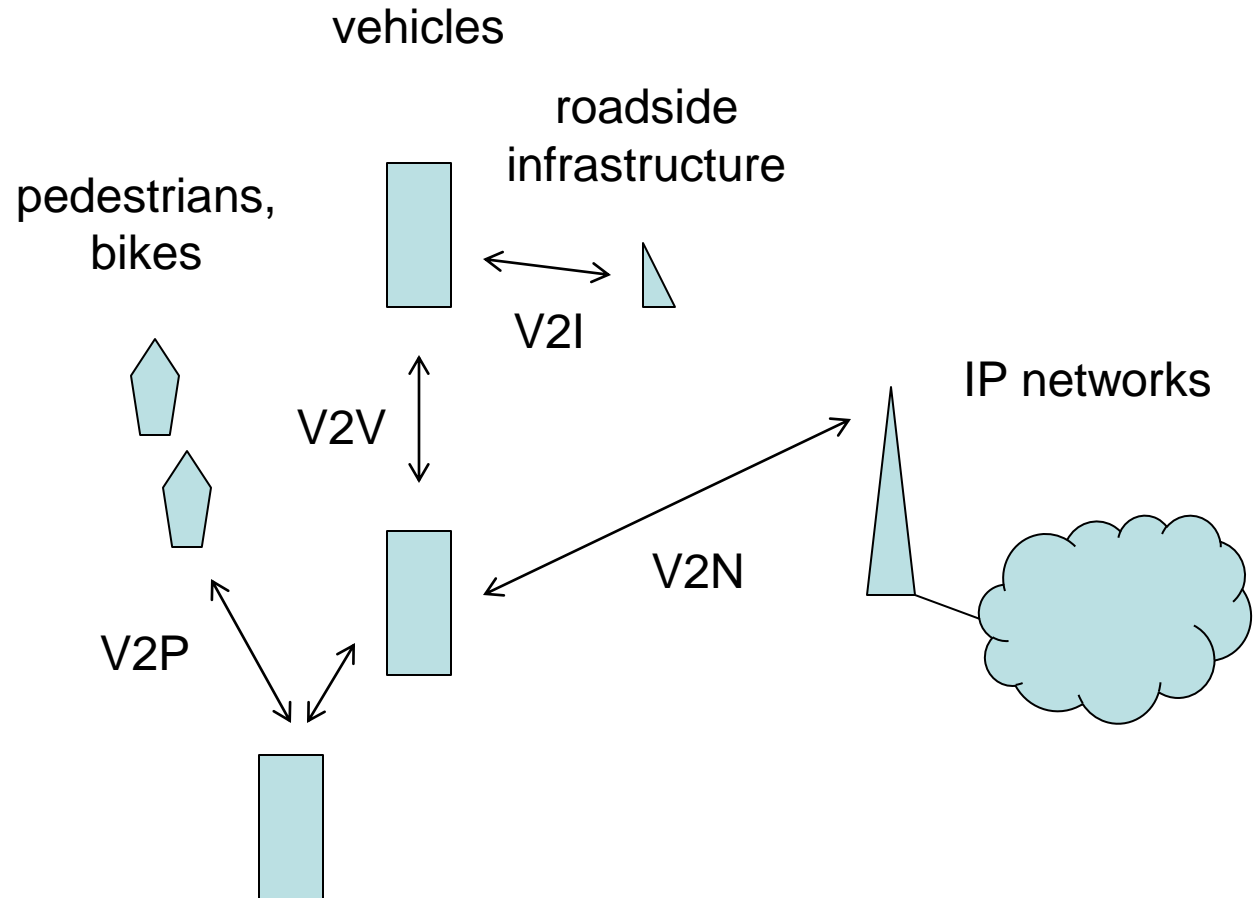
1. What protocol layers may include entities that manage retransmission of portions of data?
 2. What protocol is used in the Internet at NET? Is it connectionless or connection-oriented?
 3. What are the assumptions for Poisson traffic generated by a population of sources?
 4. How large should be an efficient antenna working at 900 MHz? And, at 60 GHz?
 5. What is the maximum antenna gain of a dipole?
 6. What are the advantages and disadvantages of using frequency bands above 6 GHz?
 7. What are the impacts of a memoryless non linear RF amplifier on the transmitted signal?
 8. Compute the maximum link spectrum efficiency for M-QASK with $M = 4, 16,$ and 64 .
 9. What is the signal bandwidth of a BPSK signal at $R_b = 1$ Mbit/s with raised cosine filters?
 10. What is the required level of SNR for BPSK with raised cosine filters at $BER = 0.001$?
 11. Compute the noise power density for a link with receiver having noise figure 6 dB.
 12. Provide definition of the noise equivalent bandwidth of a receiver.
 13. Compute the transmission range under free space conditions if $P_t = 1$ mW, frequency is 2.4 GHz, receiver sensitivity is -89 dBm and antennas are dipoles.
-

5. Network Architectures for Vehicular Communications

Network Architectures for Vehicle Communications

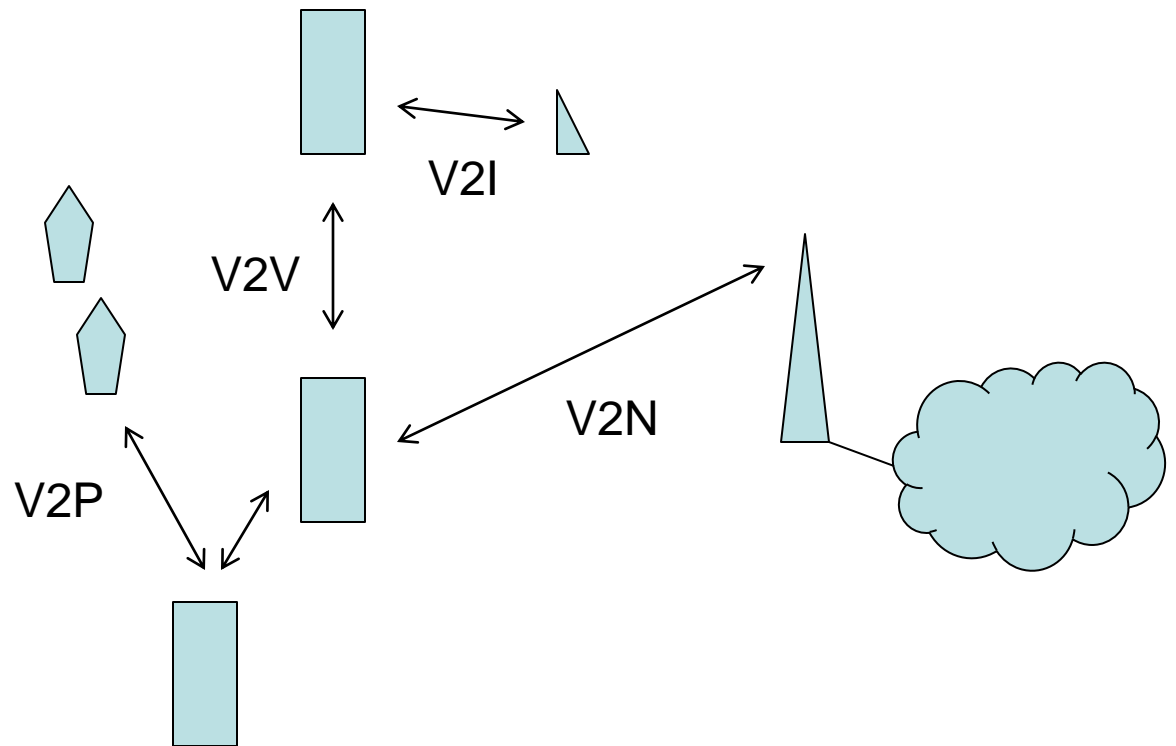
V2X = Vehicle to X (Everything)

- X = Infrastructure (V2I)
- X = Vehicles (V2V)
- X = Pedestrians (V2P)
- X = Network (V2N)



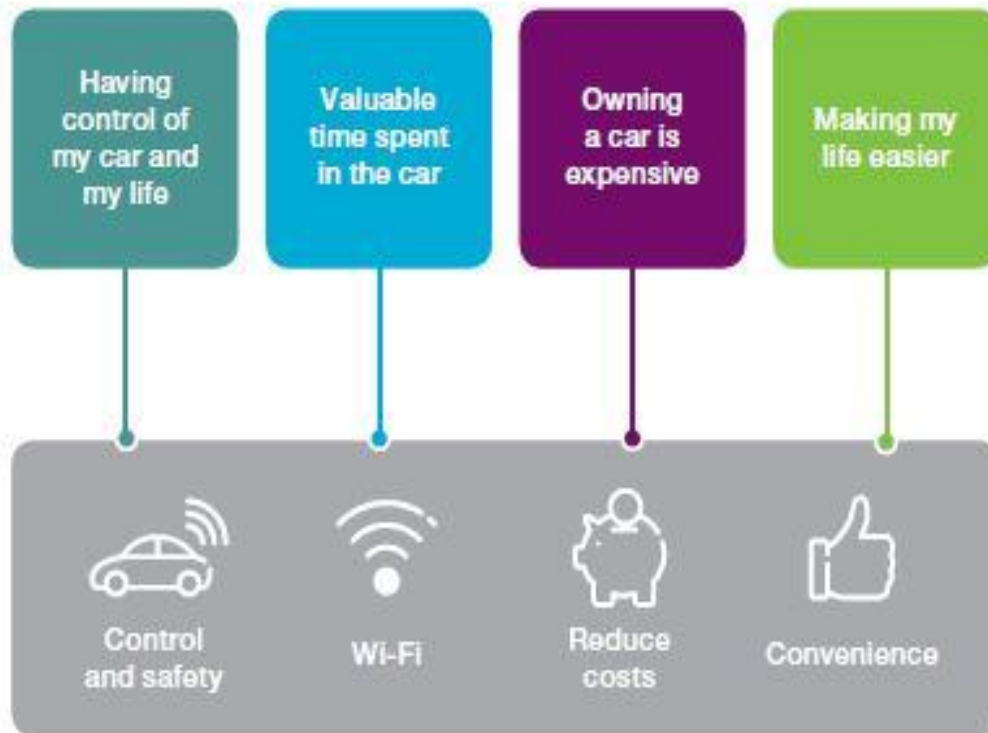
Network Architectures for Vehicle Communications

Applications ?



Network Architectures for Vehicle Communications

Main factors driving consumer interest in connected cars



Source: Telia, in-depth-interviews with car owners (2015)

Consumers who were very interested/interested in feature

Feature	Percent	Category
Car Wi-Fi*	62%	Wi-Fi hotspot
Tampering alarm	76%	Car control
Find my car and position alarm	65%	Car control
Car info dashboard	57%	Car control
Drivers' journal	50%	Car control
Alerts and warnings	71%	Car control
Vehicle inspection	37%	Service partners
Car service	39%	Service partners

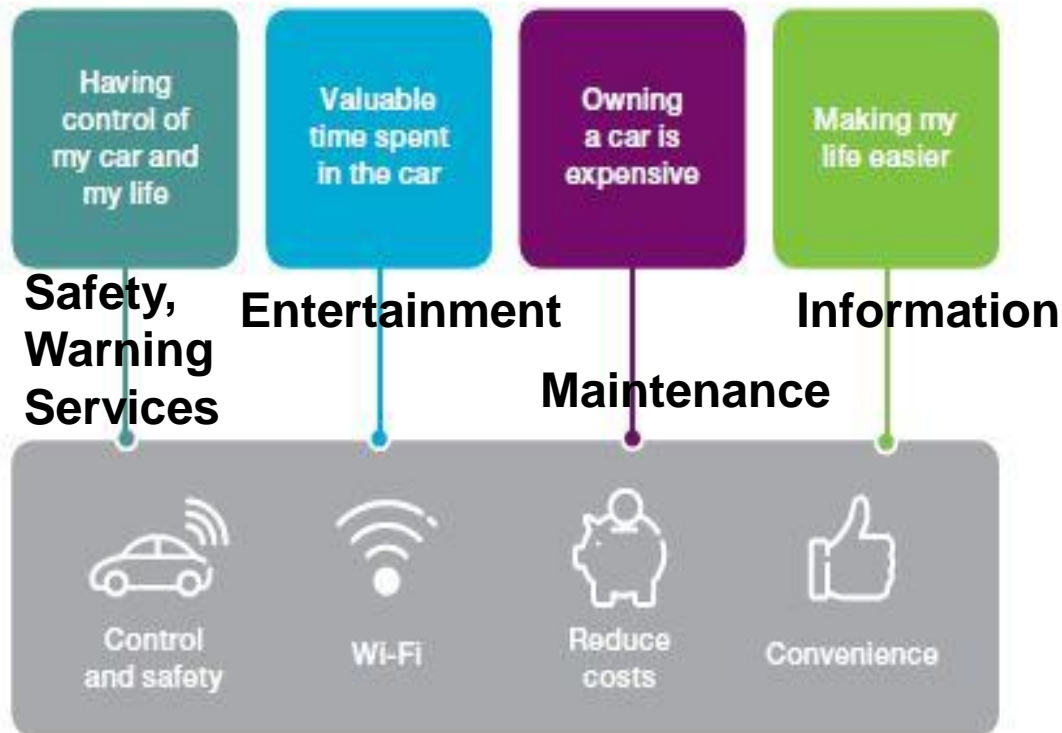
*Including 20 GB/month and data top-up possibilities

Source: Telia

Base: 502 respondents with driving licenses and access to a car, aged 18-65 in Sweden (2016)

Network Architectures for Vehicle Communications

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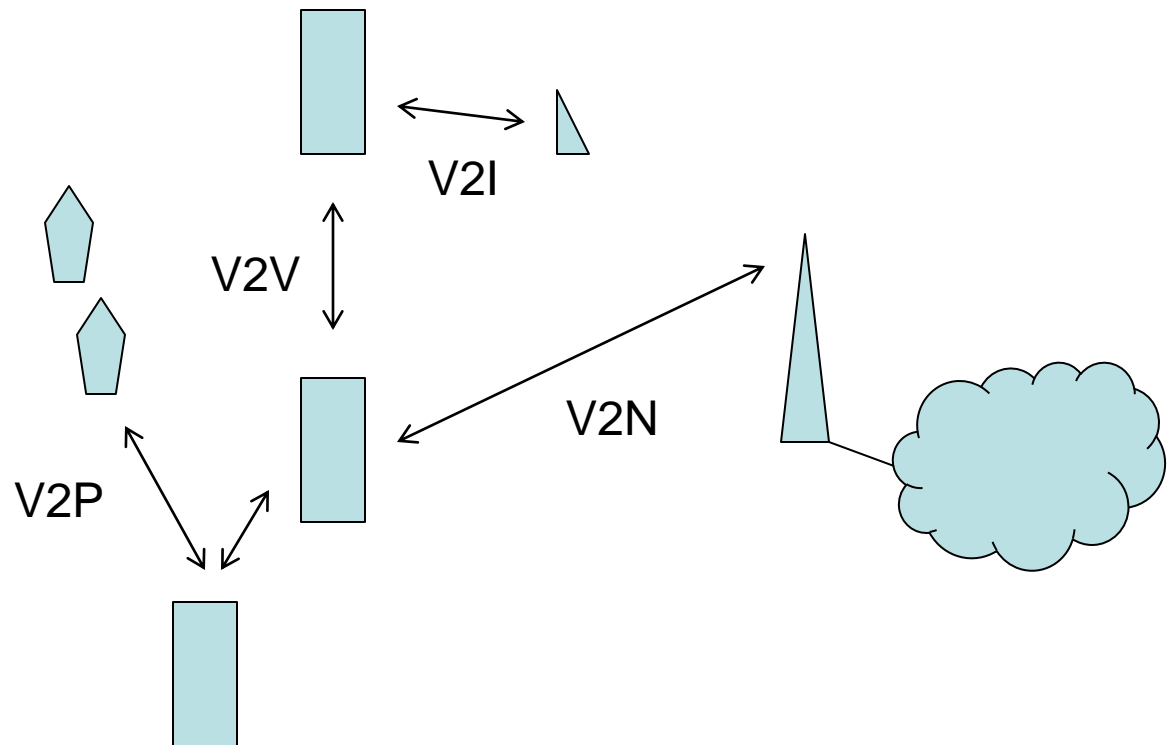
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Network Architectures for Vehicle Communications

Applications

- Information
- Entertainment
- Maintenance
- Warning Services
- Safety



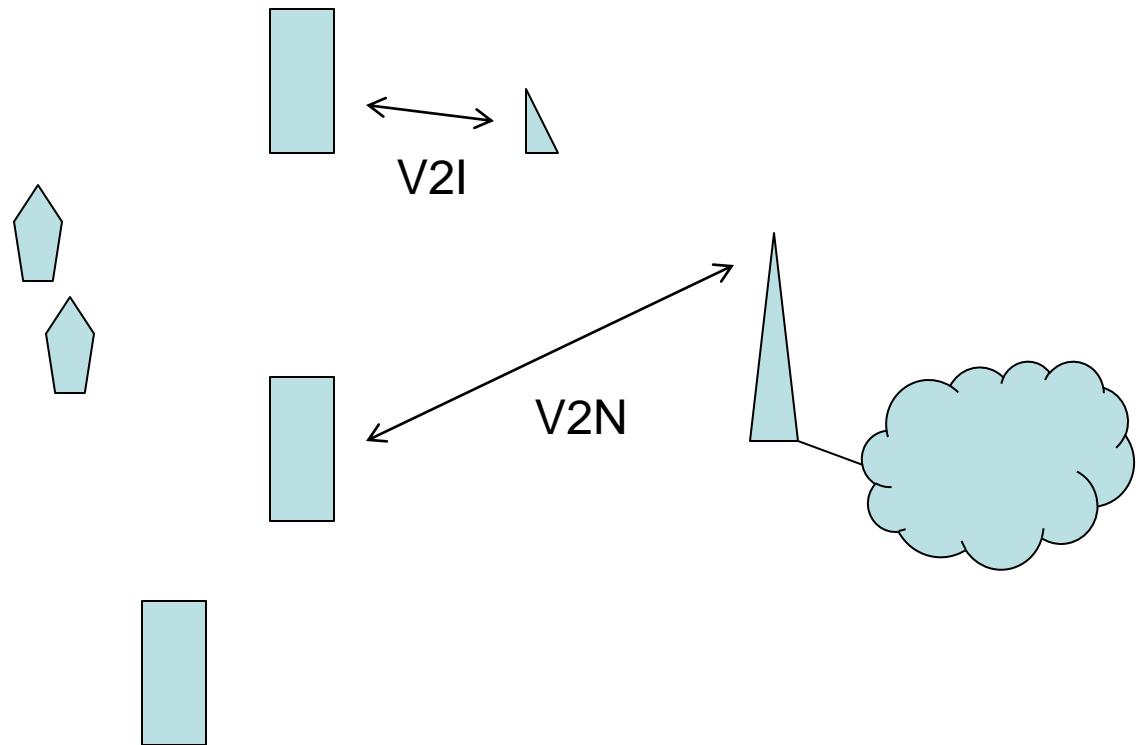
Network Architectures for Vehicle Communications

- Information

- Local
- Geographic

Requirements:

- Low-medium data rate
- Delay tolerant

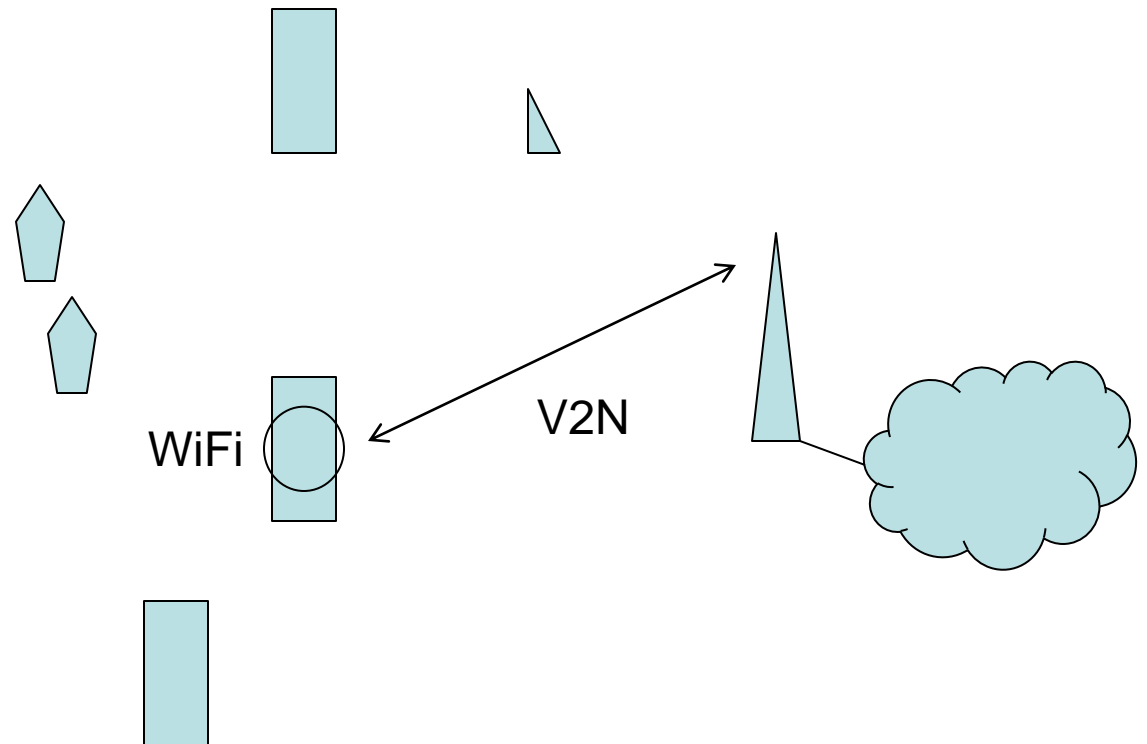


Network Architectures for Vehicle Communications

- Entertainment

Requirements:

- High data rate
- Delay constrained

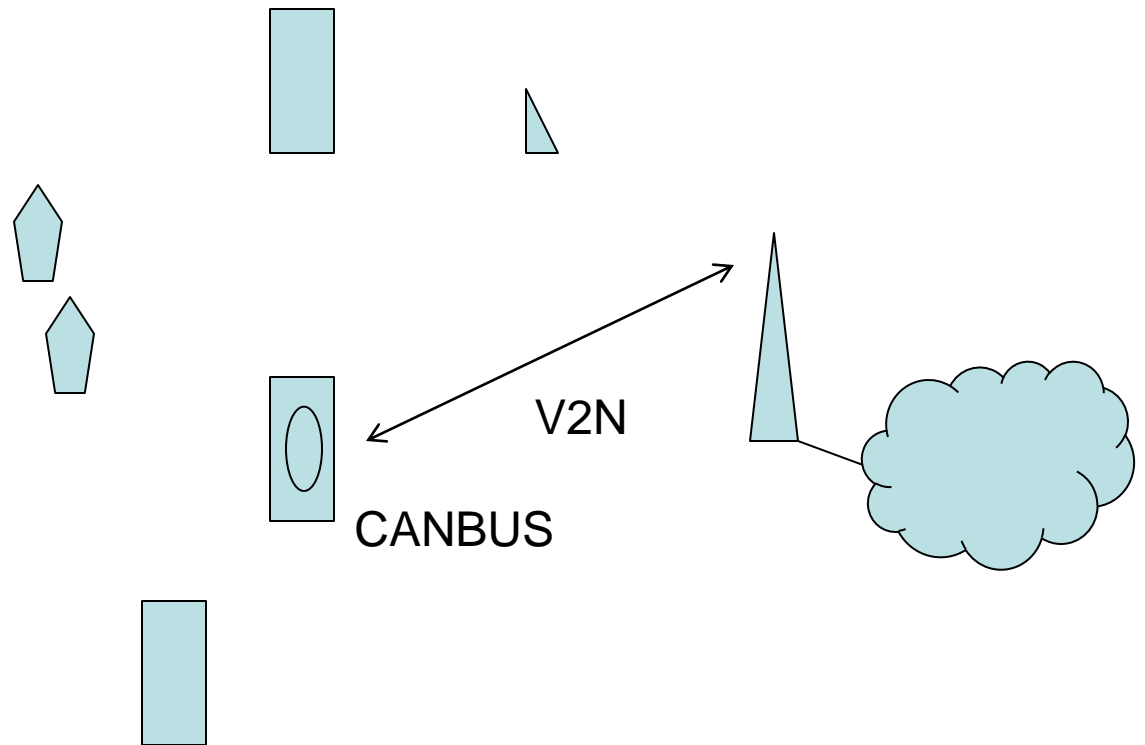


Network Architectures for Vehicle Communications

- Maintenance

Requirements:

- Low data rate
- Delay unconstrained



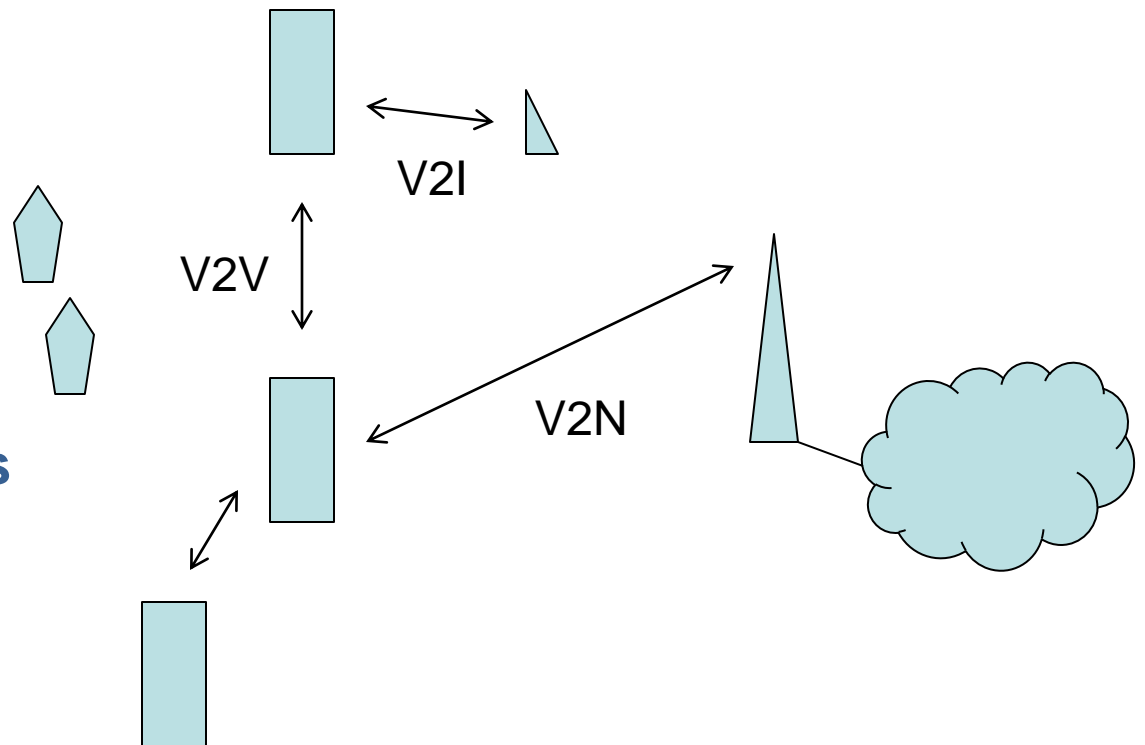
Network Architectures for Vehicle Communications

- **Warning Services**

- Road Conditions
- Traffic Conditions
- ...

Requirements:

- Low-medium data rate
- Stringent delay constraints



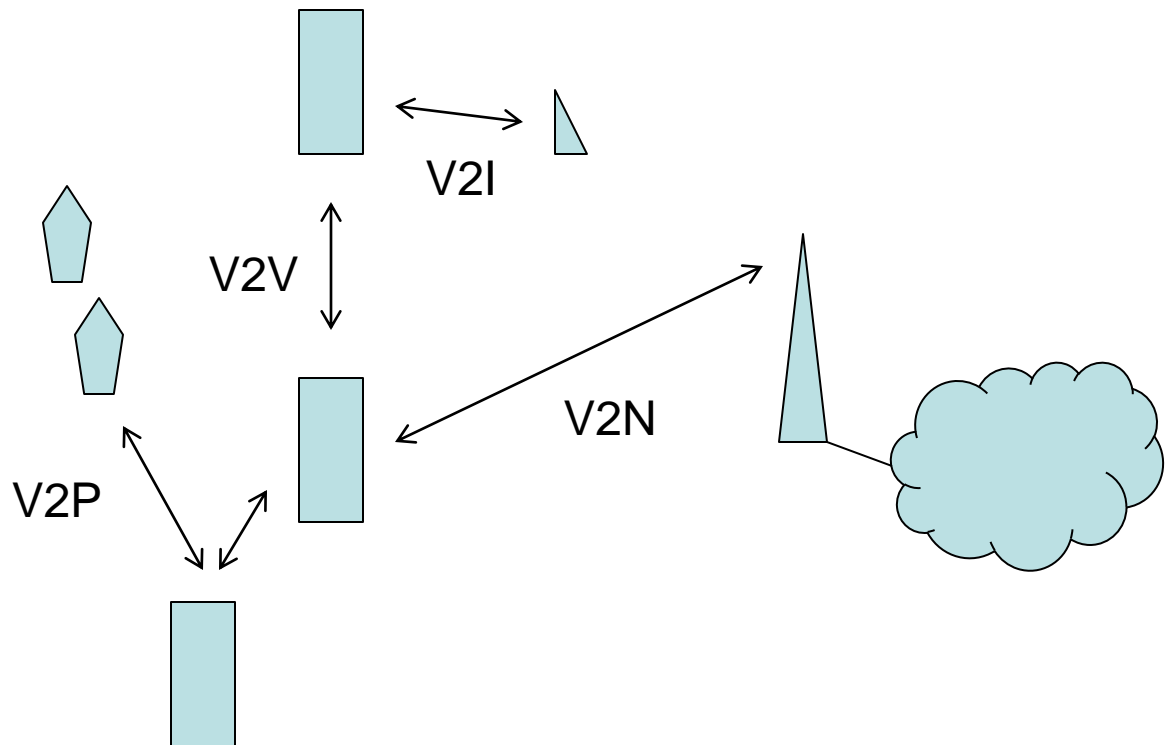
Network Architectures for Vehicle Communications

- **Safety**

- **Indication**
- **Warning**

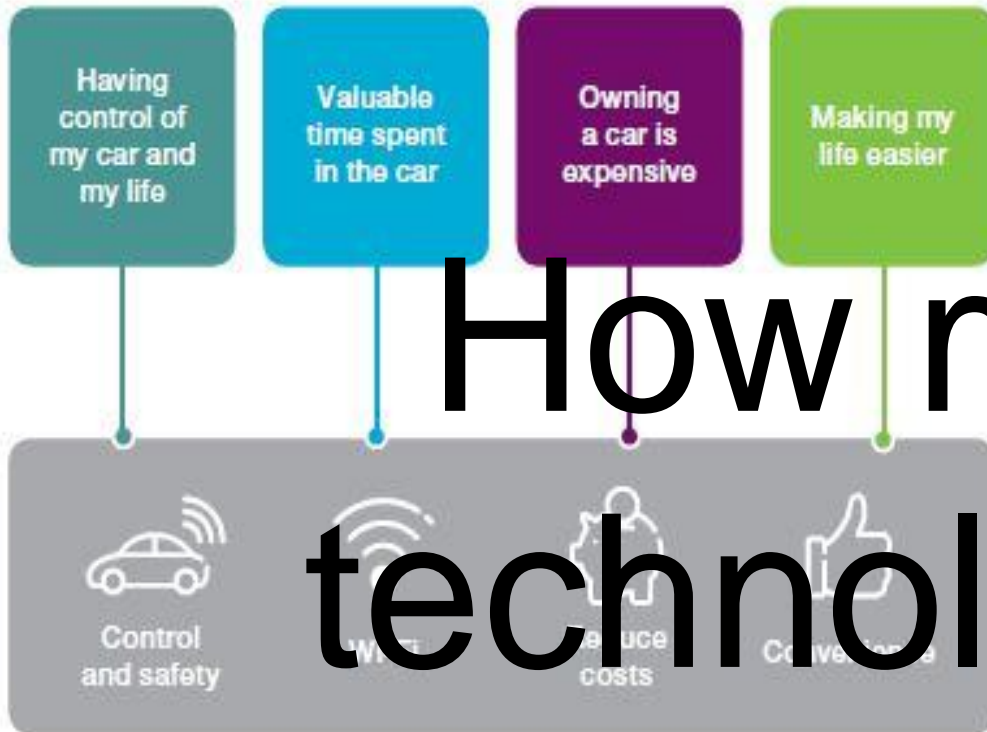
Requirements:

- **High data rate**
- **Ultra-stringent delay constraints**



Network Architectures for Vehicle Communications

Main factors driving consumer interest in connected cars



How many technologies?

Consumers who were very interested/interested in feature

Feature	Percent	Category
Car Wi-Fi*	62%	Wi-Fi hotspot
Tampering alarm	76%	Car control
Find my car and position alarm	65%	Car control
Car info dashboard	57%	Car control
Drivers' journal	50%	Car control
Alerts and warnings	71%	Car control
Vehicle inspection	51%	Service partners
Car services	39%	Service partners

*Including 20 GB/month and data top-up possibilities

Source: Telia

Base: 502 respondents with driving licenses and access to a car, aged 18-65 in Sweden (2016)