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Bretagne-Pays de la Loire
École Mines-Télécom

INTRODUCTION TO INTERNET OF THINGS

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OCIF - OBJETS COMMUNICANTS ET INTERNET DU FUTUR

The Internet of Things

Mesh network vs long range radio

End-to-end connectivity

Consumer-producer loop

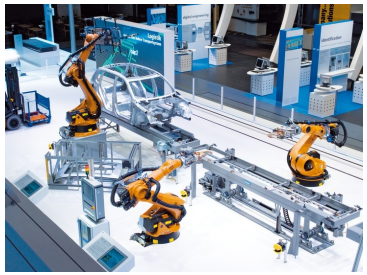
Security

Smart grid

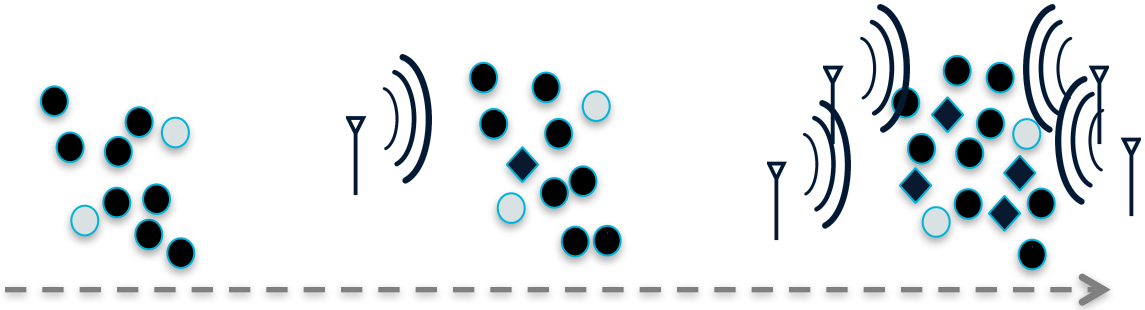
Scalability

Smart city

Quality of service

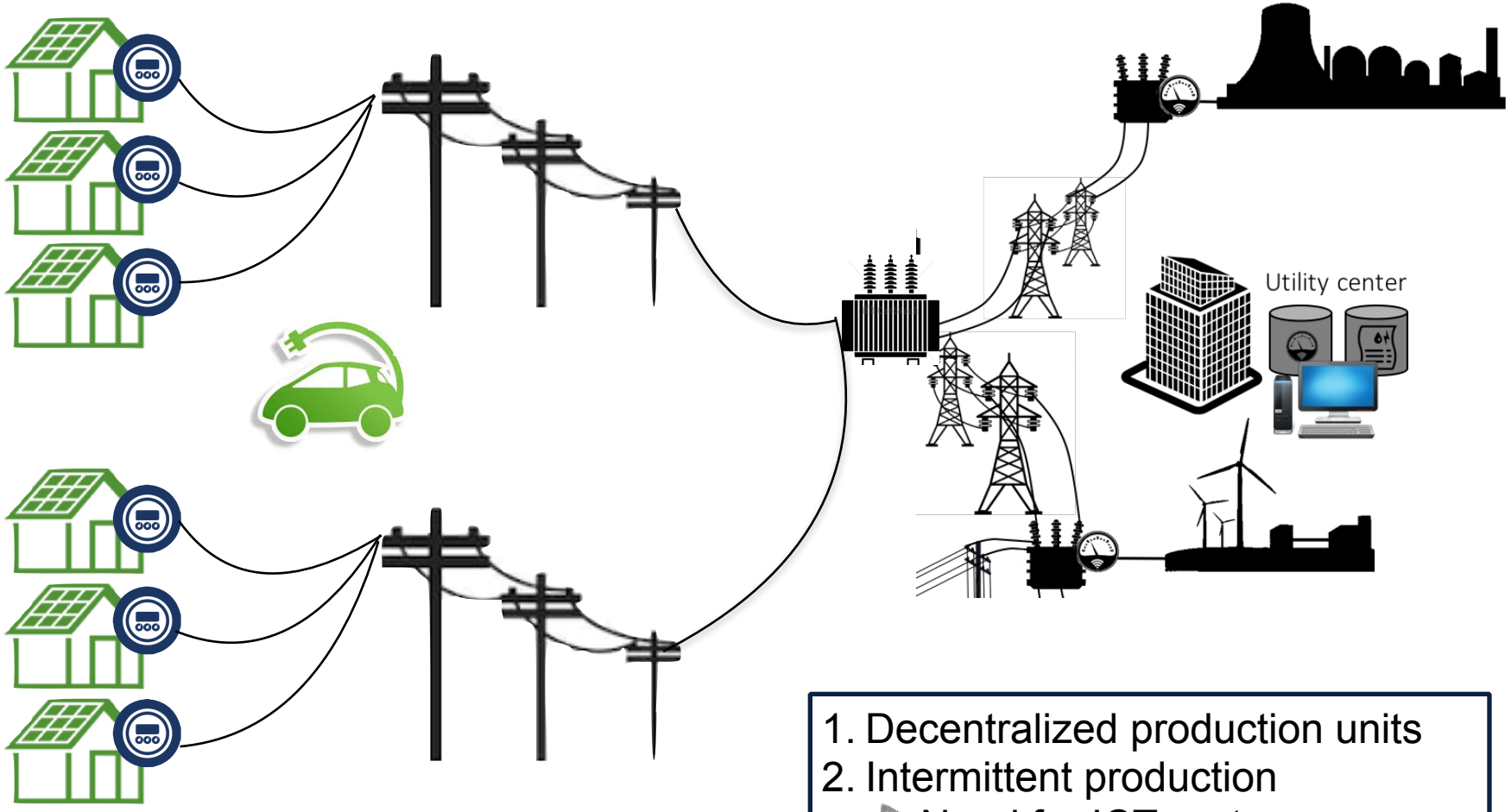


Industry 4.0



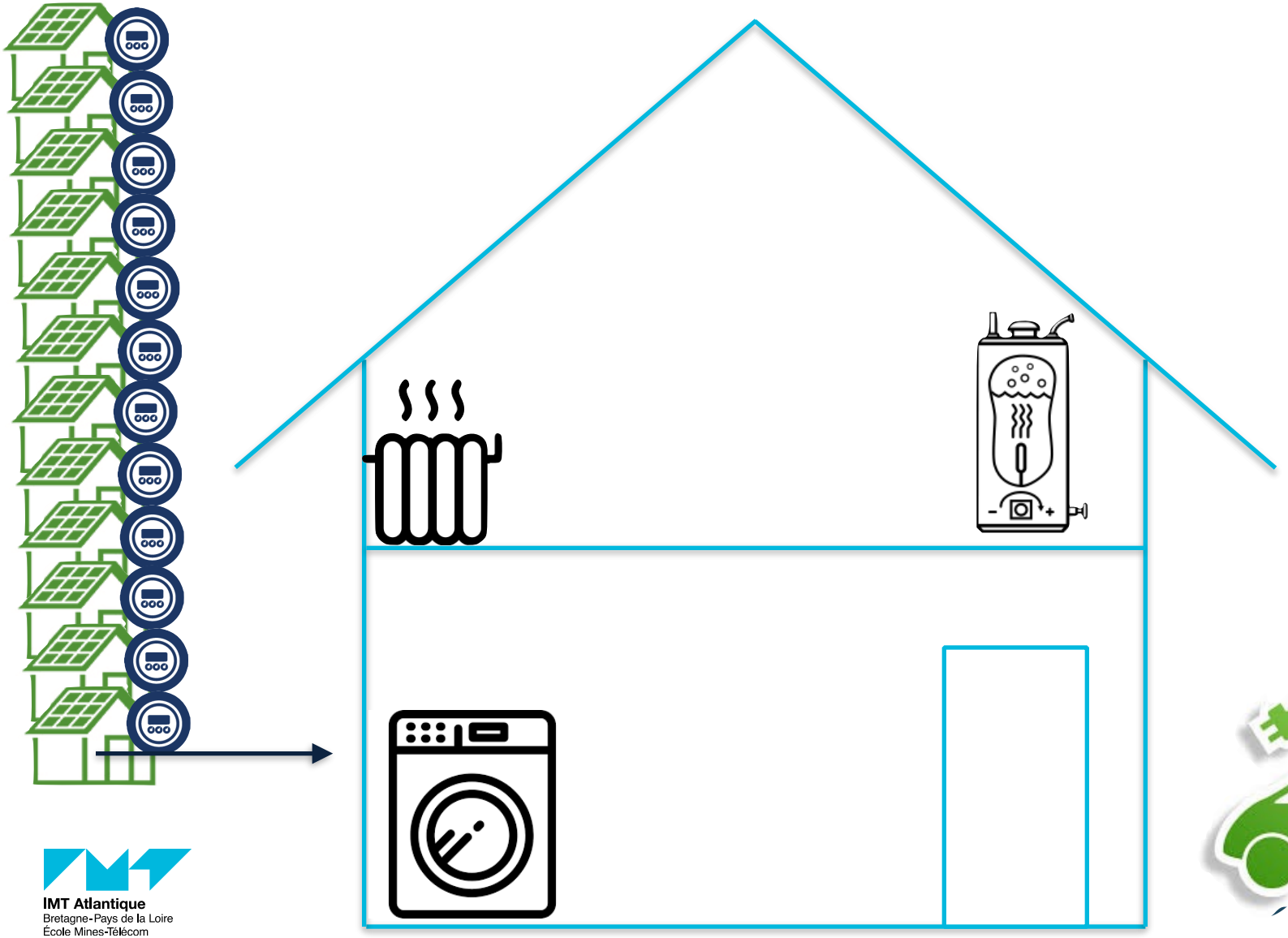
Unified access network for heterogeneous applications

SMART GRID - HOW WE SEE THINGS



1. Decentralized production units
2. Intermittent production
   - Need for ICT system
     - Shift the demand
     - Monitor in real time

SMART GRID - HOW WE SEE THINGS



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SMART GRID - SMART PLUG

Program

The Atmel Atmega128RFA1 microcontroller can easily run customized programs powered by the Contiki Operating System.

Monitor

Plug in an electric device and retrieve informations about its electric consumption in real time.

Collect

The integrated low power tranceiver 802.15.4 chip allows easy wireless interactions with one or more smartplugs.

Control

The Smartplug is equiped with a relay allowing the device the turn the current on or off.

INTRODUCTION

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WHAT IS THE INTERNET?

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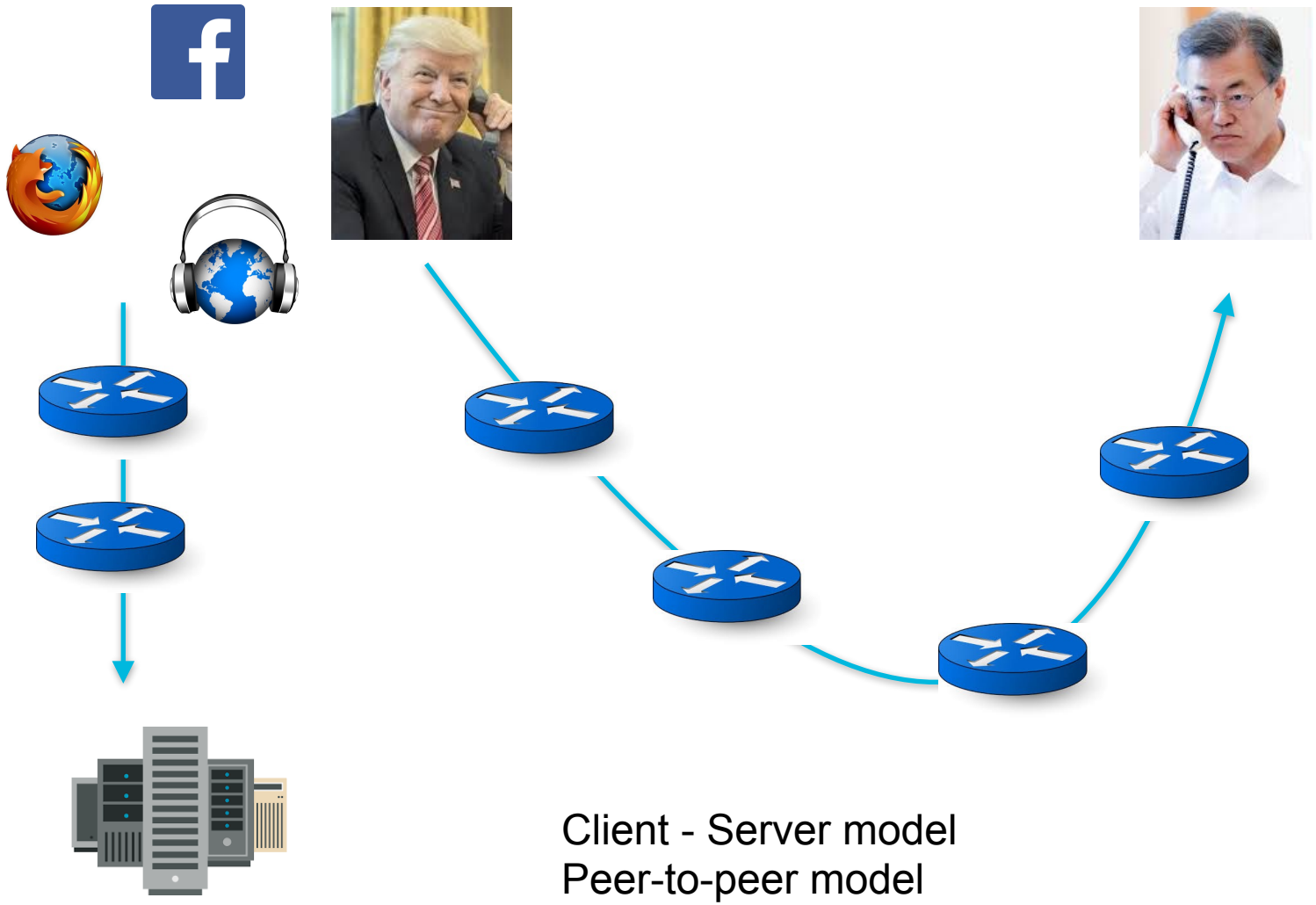
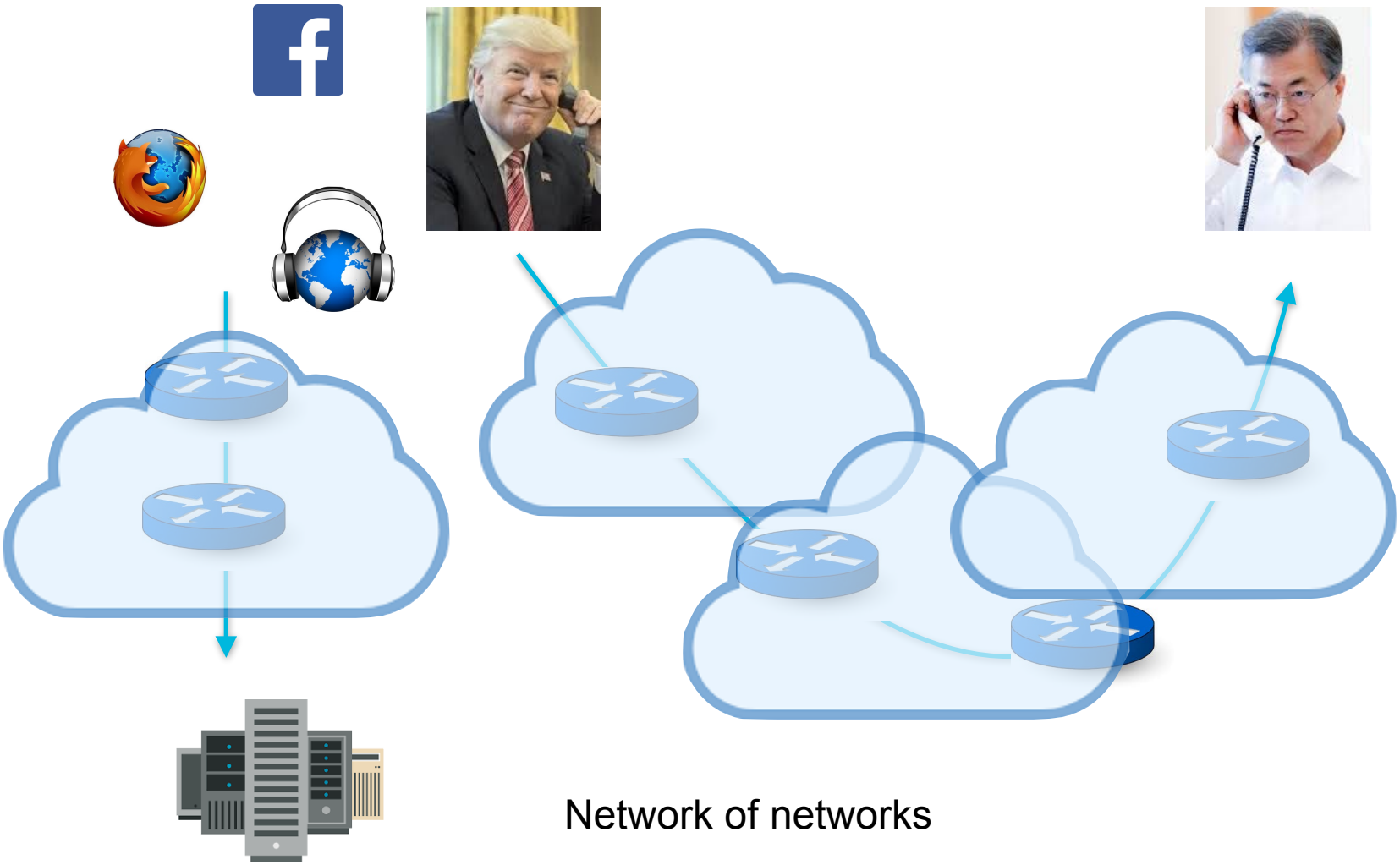


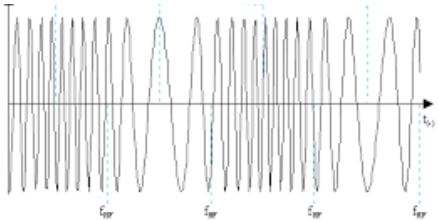
Client - Server model
Peer-to-peer model

WHAT IS THE INTERNET?



Network of networks

LAYERED APPROACH



Application

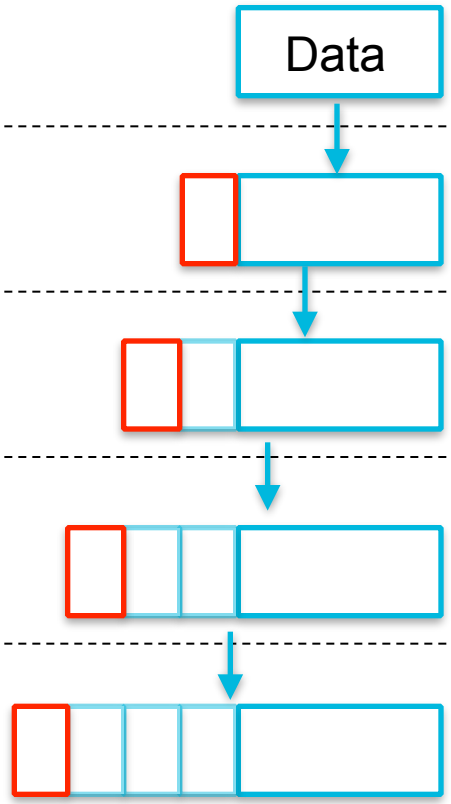
UDP TCP

Transport

Network

Link / MAC

Physical layer

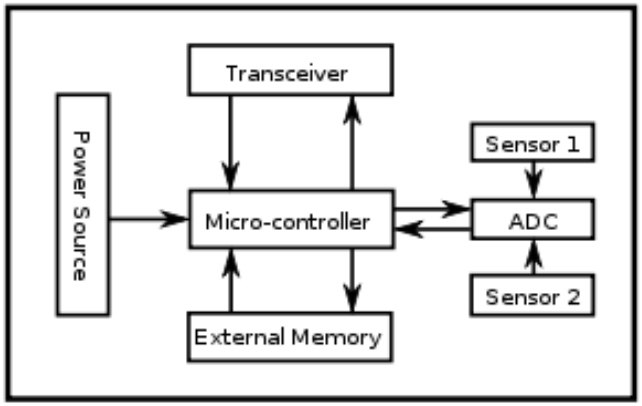


WHAT ARE THE STRENGTH OF THE INTERNET?

- Worldwide
- Standard
- Multi-applications
- Multi-technologies
- Works whatever the link capacity

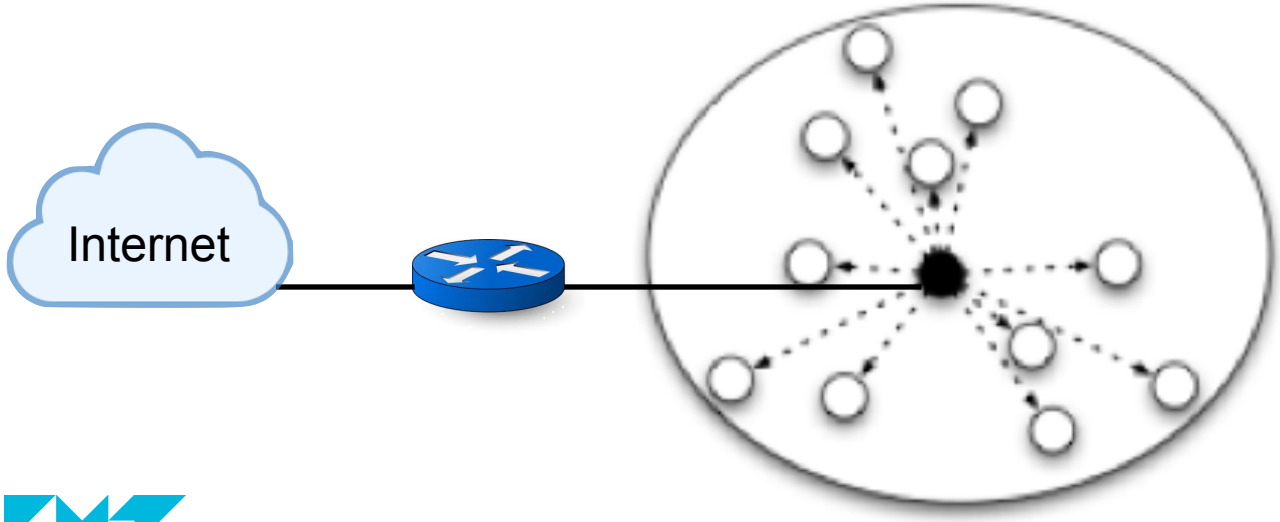
So why not using it for the things (i.e., sensors, objects)?

THE INTERNET OF THINGS



Things

Connected



LAYERED APPROACH

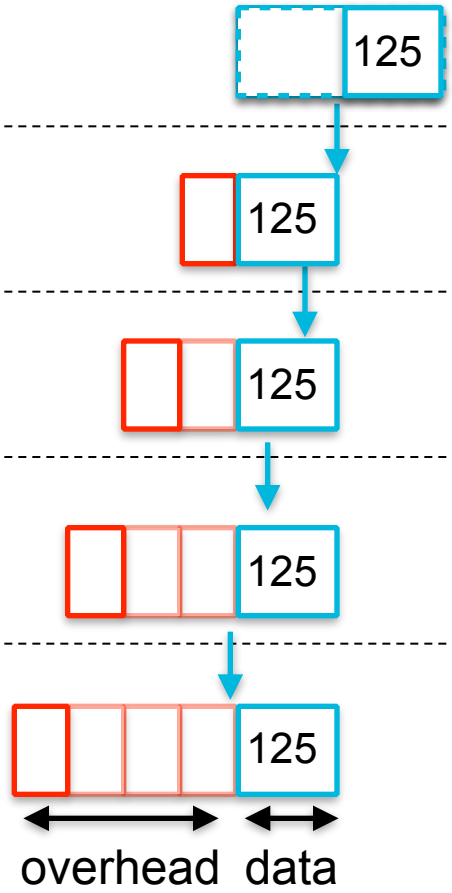
Application

Transport

Network

Link / MAC

Physical layer



Bluetooth 4.0 Low Energy

sigfox

LoRa

ISA 100 WIRELESS

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LAYERED APPROACH

Long Range

	range	bitrate	frequency
SigFox	13 km	100 bps	900MHz
LTE-M	15 km	150 kbps – 1 Mbps	licensed 900MHz
LoRa	11 km	10 kbps	900MHz

Short Range

	range	bitrate	frequency
IEEE 802.15.4	**10 m**	**250 Kbps**	**2.4GHz**
Wi-Fi HaLow	1 km	150 kbps – 1 Mbps	900MHz
BLE	100 m	125 kbps – 2Mbps	2.4GHz

LAYERED APPROACH

Routing

Application

COAP / DTLS

UDP

TCP

Transport

Network

@ / Routing

Link / MAC

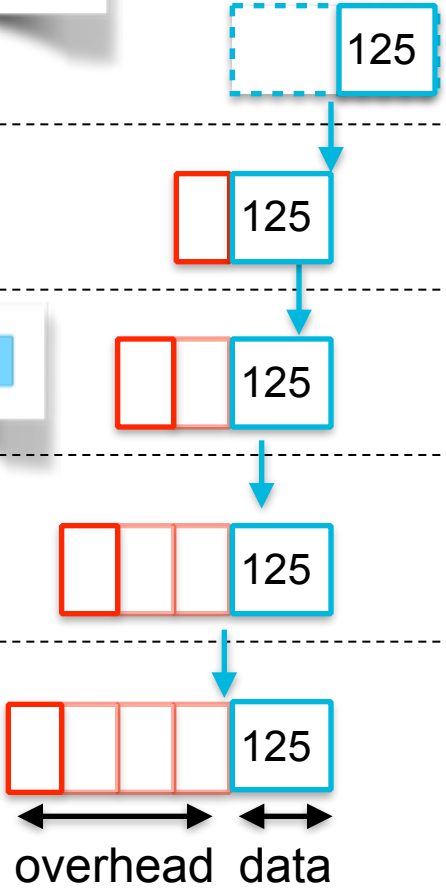
Physical layer

Bluetooth 4.0 Low Energy

sigfox

LoRa

ISA 100 WIRELESS



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6LOWPAN

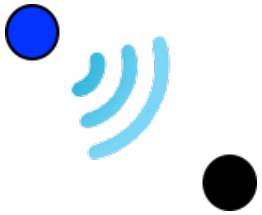
- Header Size Calculation. . .
  - IPv6 header is 40 bytes, UDP header is 8 bytes
  - 802.15.4 MAC header can be up to 25 bytes (null security) or 25+21=46 bytes (AES-CCM-128)
  - With the 802.15.4 frame size of 127 bytes:

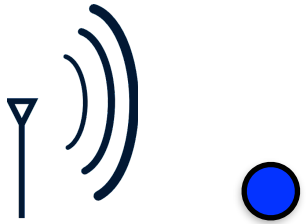
    127-25-40-8 = 54 bytes (null security)

    127-46-40-8 = **33 bytes** (AES-CCM-128)

- IPv6 MTU Requirements
  - IPv6 requires that links support an MTU of 1280 bytes
  - Header compression &
  - Link-layer fragmentation / reassembly is needed

COMPRESSION





Variable
Line
oriented

HTTP header

20 Bytes

TCP

40 Bytes

IPv6

Layer 2

4+ Bytes

CoAP

Messages

Transport

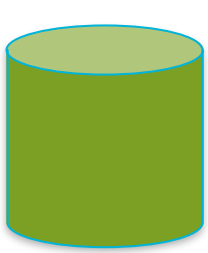
8 Bytes

UDP

4-20 Bytes

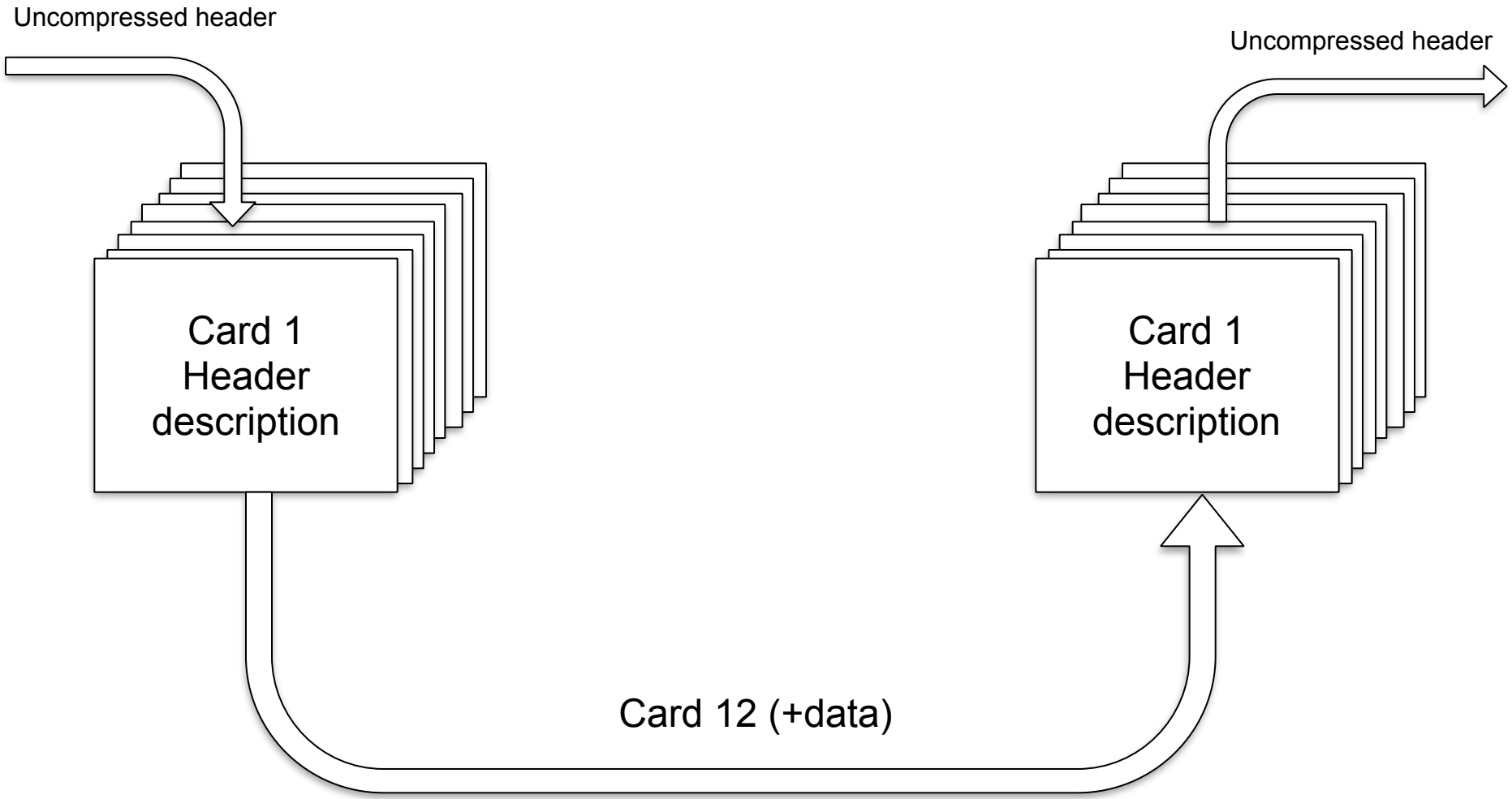
6LoWPAN

Layer 2



Layer 2

Static Context Header Compression



LAYERED APPROACH

Routing

Application

COAP / DTLS

UDP | TCP

Transport

Network

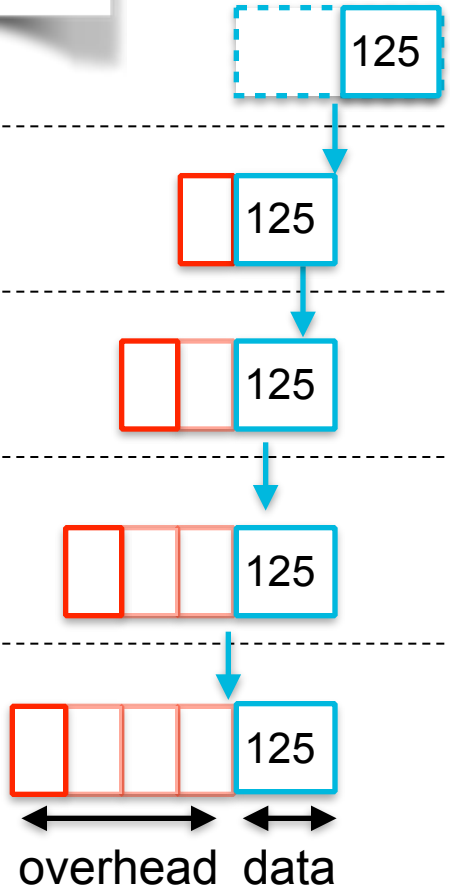
Adaption layer

Link / MAC

6top

Physical layer

Bluetooth 4.0 Low Energy | sigfox | LoRa | ISA100 WIRELESS



THE INTERNET OF THINGS

Benefits

- Worldwide
- Standard
- Multi-applications
- Multi-technologies
- Works whatever the link capacity

Challenges

- Adapted wireless technologies
  - Low energy consumption
  - Low capacity: low data rate, lossy, short frame, high delay
- Large overhead
  - Compression
- Data representation
- Routing

MEDIUM ACCESS CONTROL

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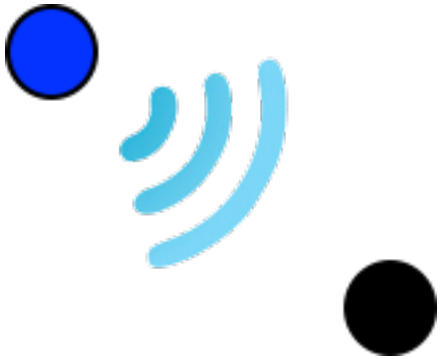
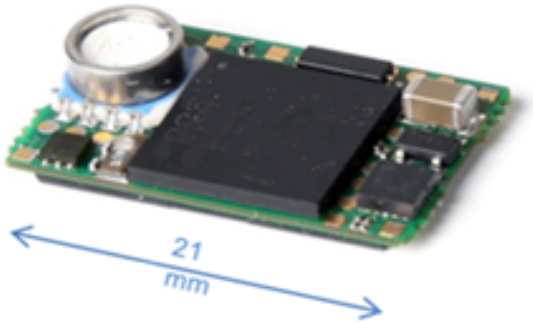
MEDIUM ACCESS CONTROL

- Objective: share the medium access
  - Who can send?
  - When a node should expect to receive data?
  - With the following goals
    - fairness
    - reliability
    - scalability
    - low latency
    - air throughput
    - **low energy consumption**

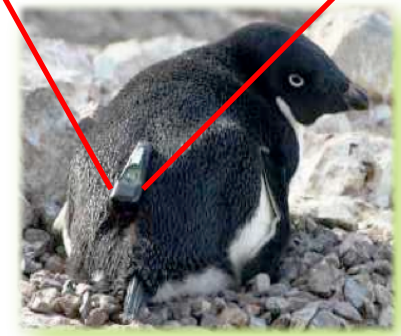


LET'S CONNECT THE THINGS

Sensor node



Bio-logger



Battery lifetime: 2 years

Battery lifetime: < 1 month

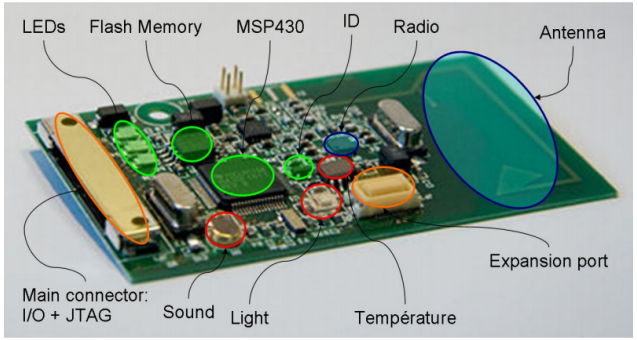
3 4G

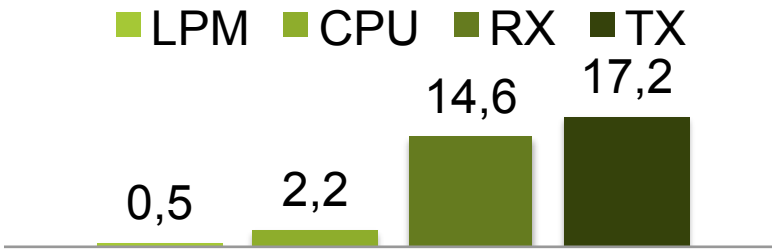
Wi Fi

Bluetooth

ZigBee

Wireless sensor node





Electricity consumption (mA)
of electronic components [1]

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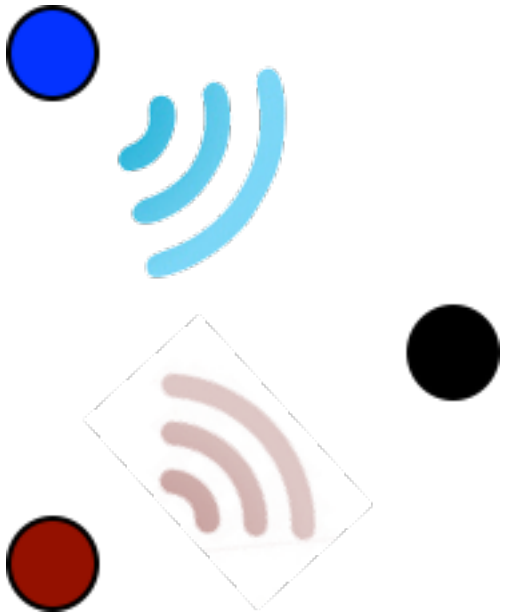
[1] J. Eriksson, F. Österlind, N. Finne, A. Dunkels, N. Tsiftes and T. Voigt, "Accurate Network-Scale Power Profiling for Sensor Network Simulators", Wireless Sensor Networks, 2009.

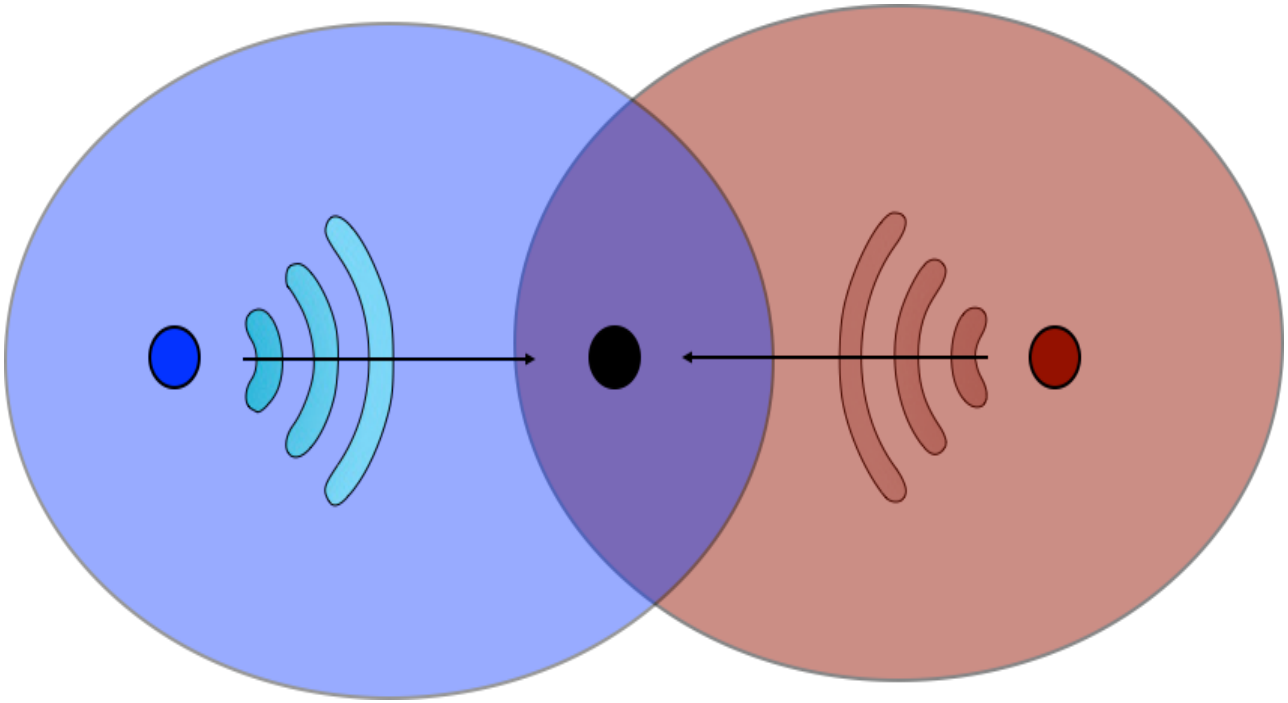
MEDIUM ACCESS CONTROL

- More than 100 MAC proposals for sensor networks
- Source of energy consumption
  - Receive / transmit
  - Idle listening
  - Control packets
  - Overhearings
  - Collisions

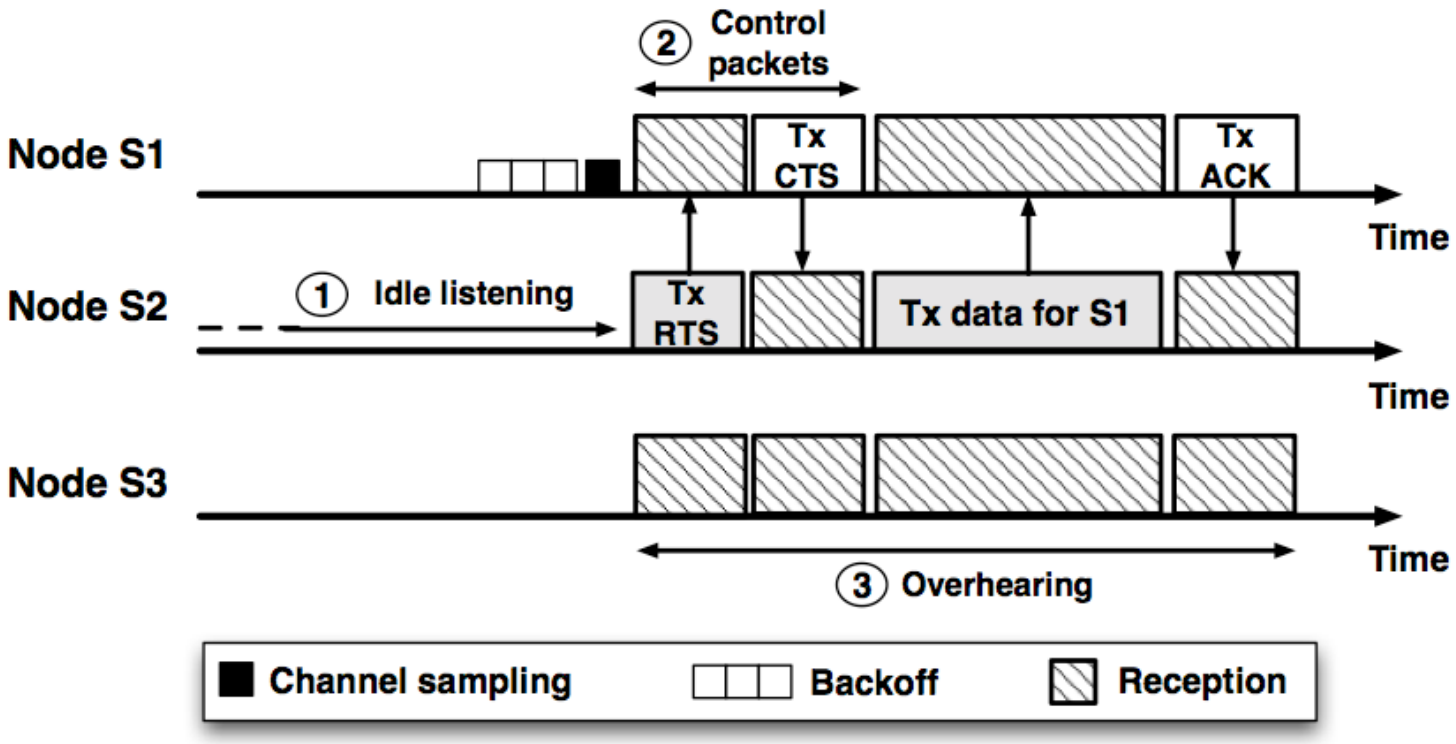
A COLLISION EXAMPLE



HIDDEN NODE PROBLEM

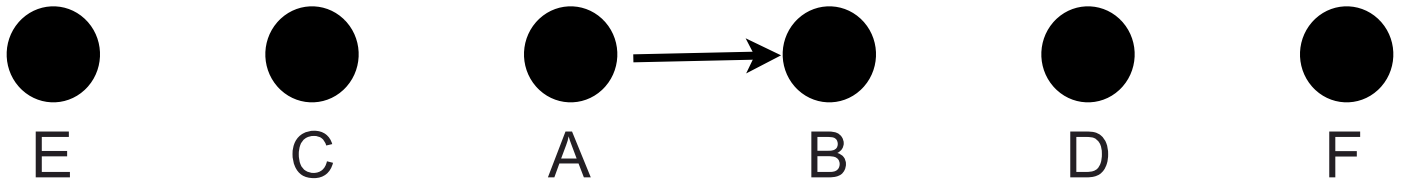


OVERHEARING AND IDLE LISTENING



ENERGY SAVING: SLEEP!

- Bluetooth low energy says that devices sleep 99% of the time
- At least the receiver must not sleep
- Parallel communication
  - Who could sleep?



A is transmitting to B

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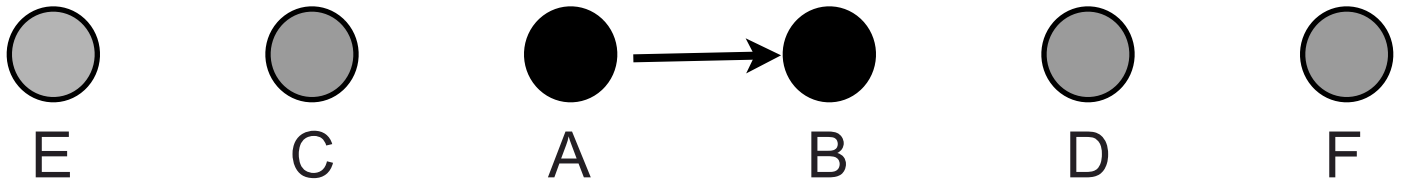

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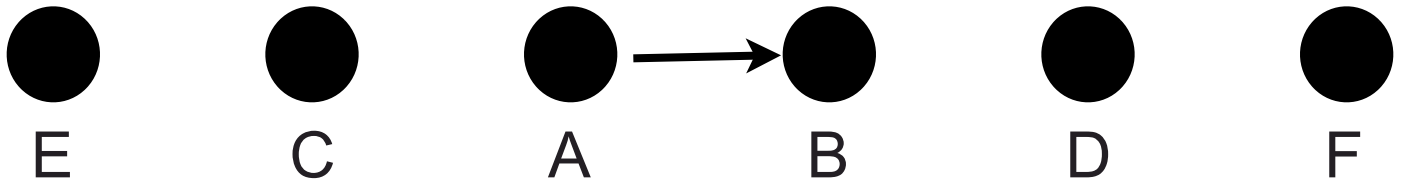

A is transmitting to B

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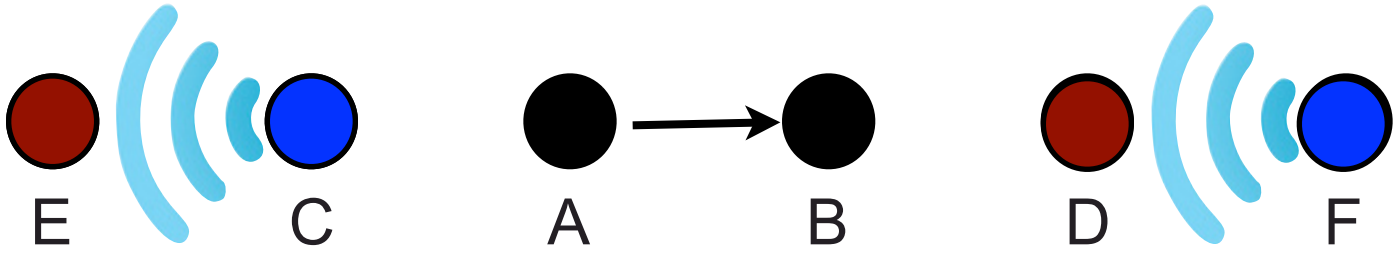
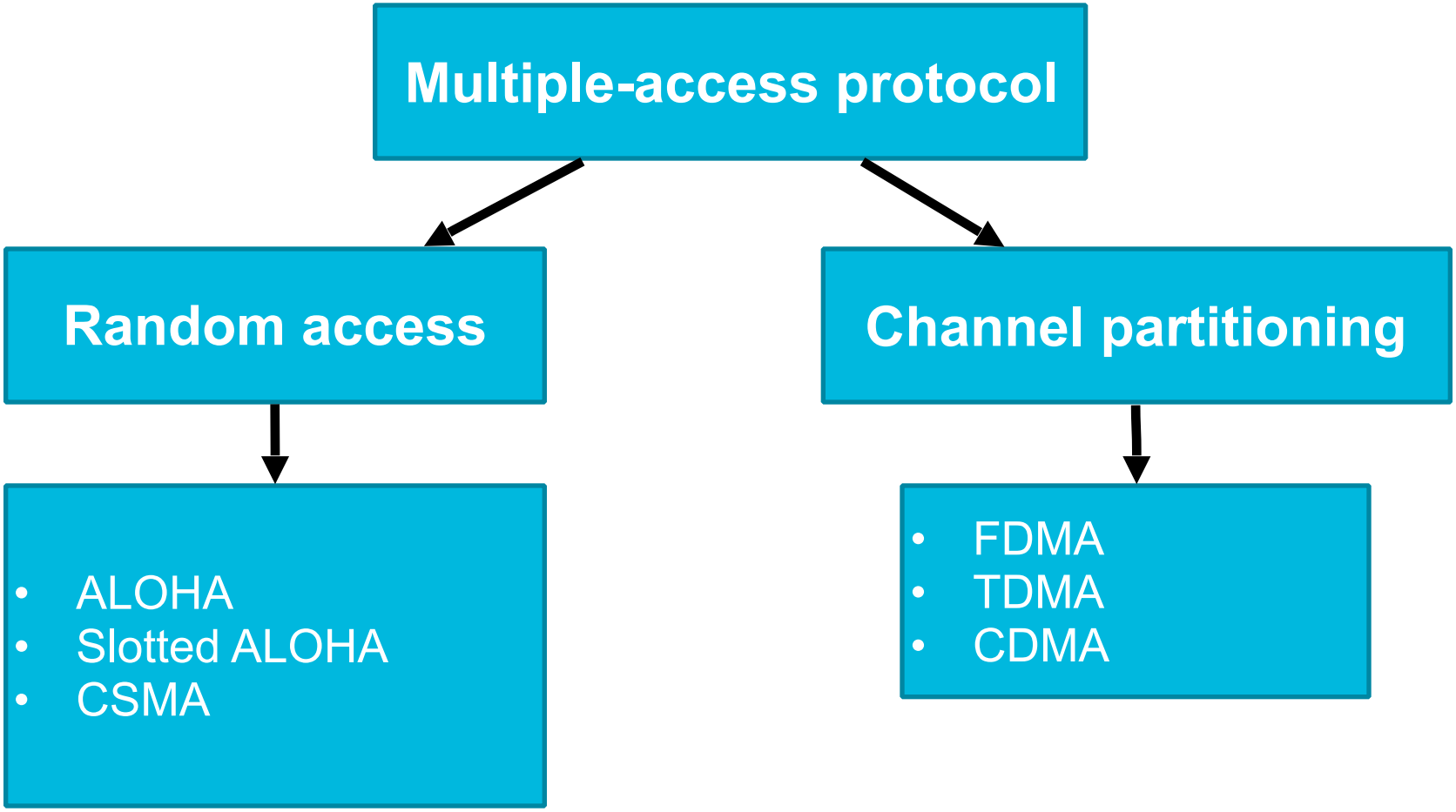
  - Who could sleep?
  - We can send?



A is transmitting to B

CHANNEL (MEDIUM) ACCESS METHODS



CHANNEL PARTITIONING

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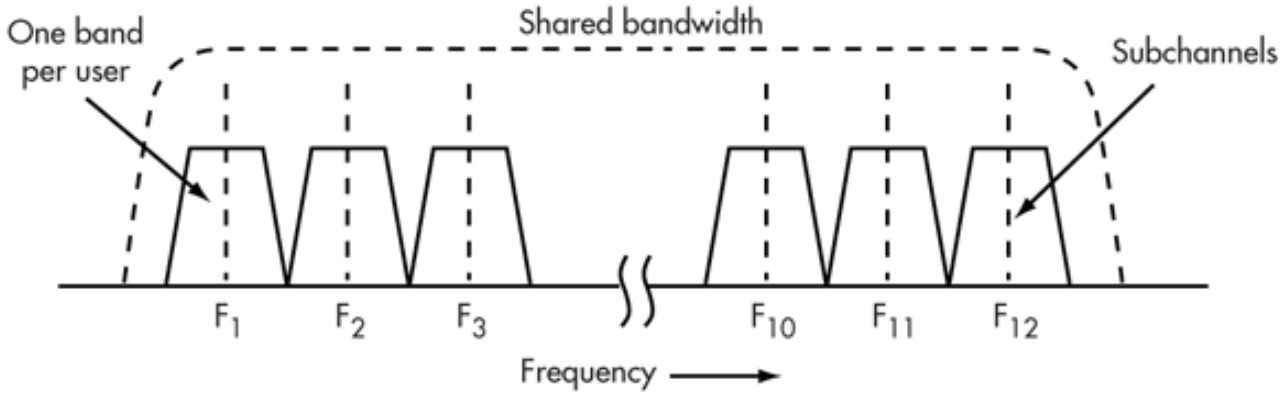
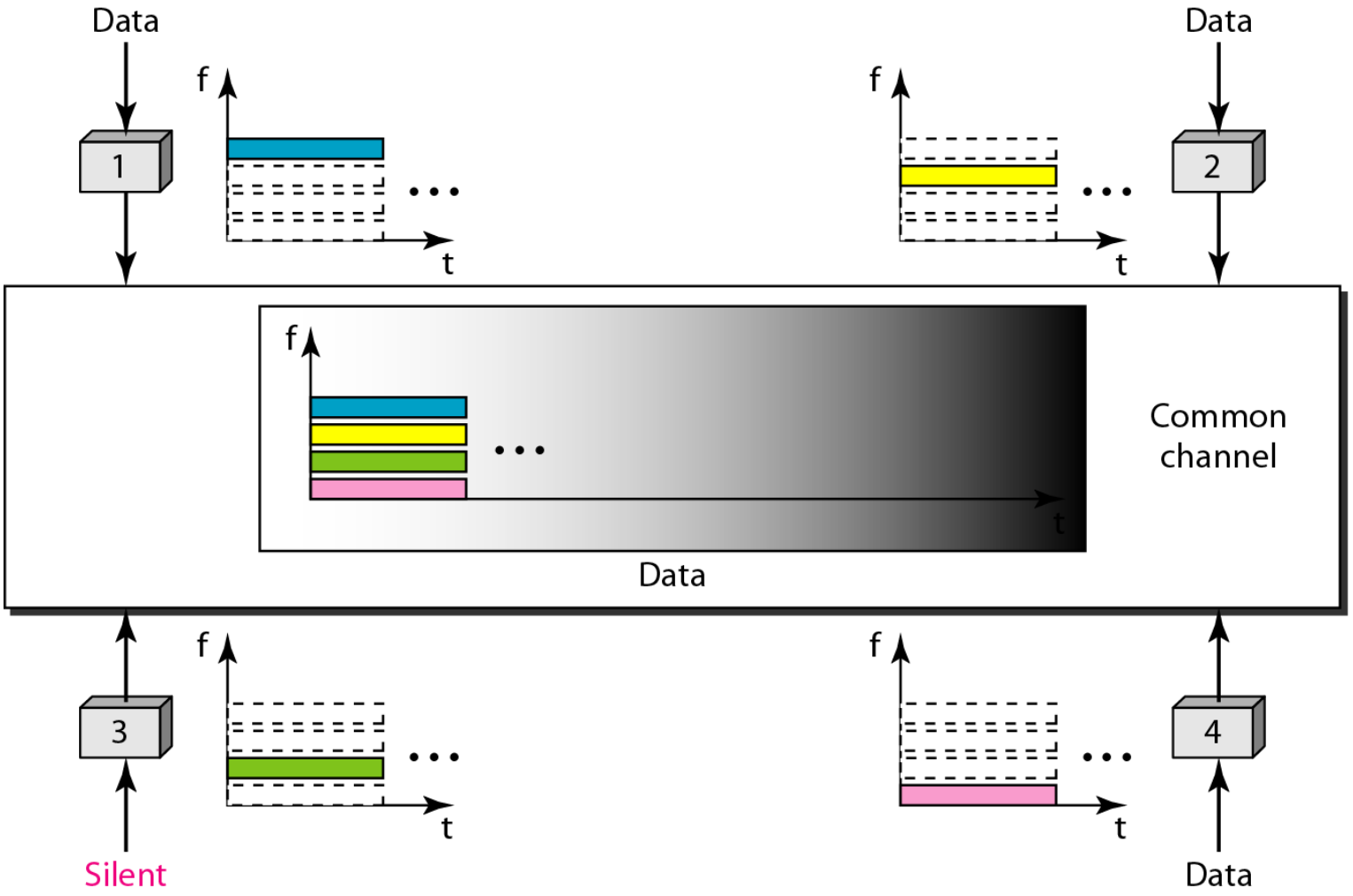
FREQUENCY-DIVISION MULTIPLE ACCESS (FDMA)

Under FDMA method, the available channel or bandwidth is divided into multiple individual bands that are separated by guard bands, each for use by a single user.



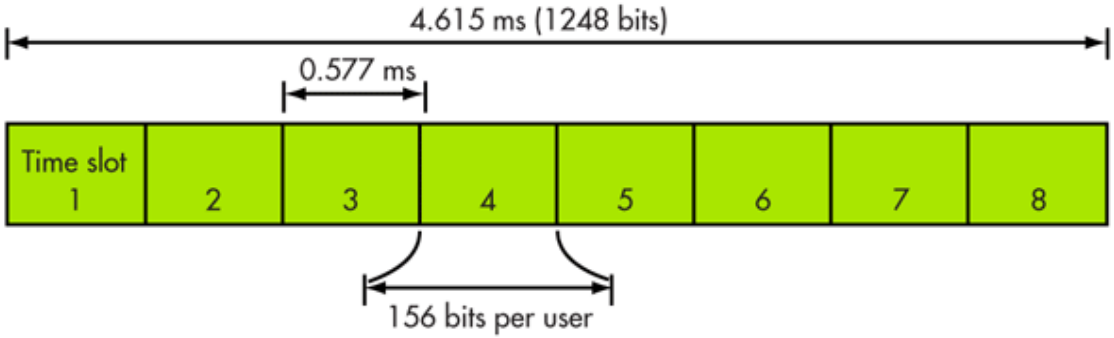
http://www.electronicdesign.com/communications/fundamentals-communications-access-technologies-fdma-tdma-cdma-ofdma-and-sdma

FDMA: EXAMPLE



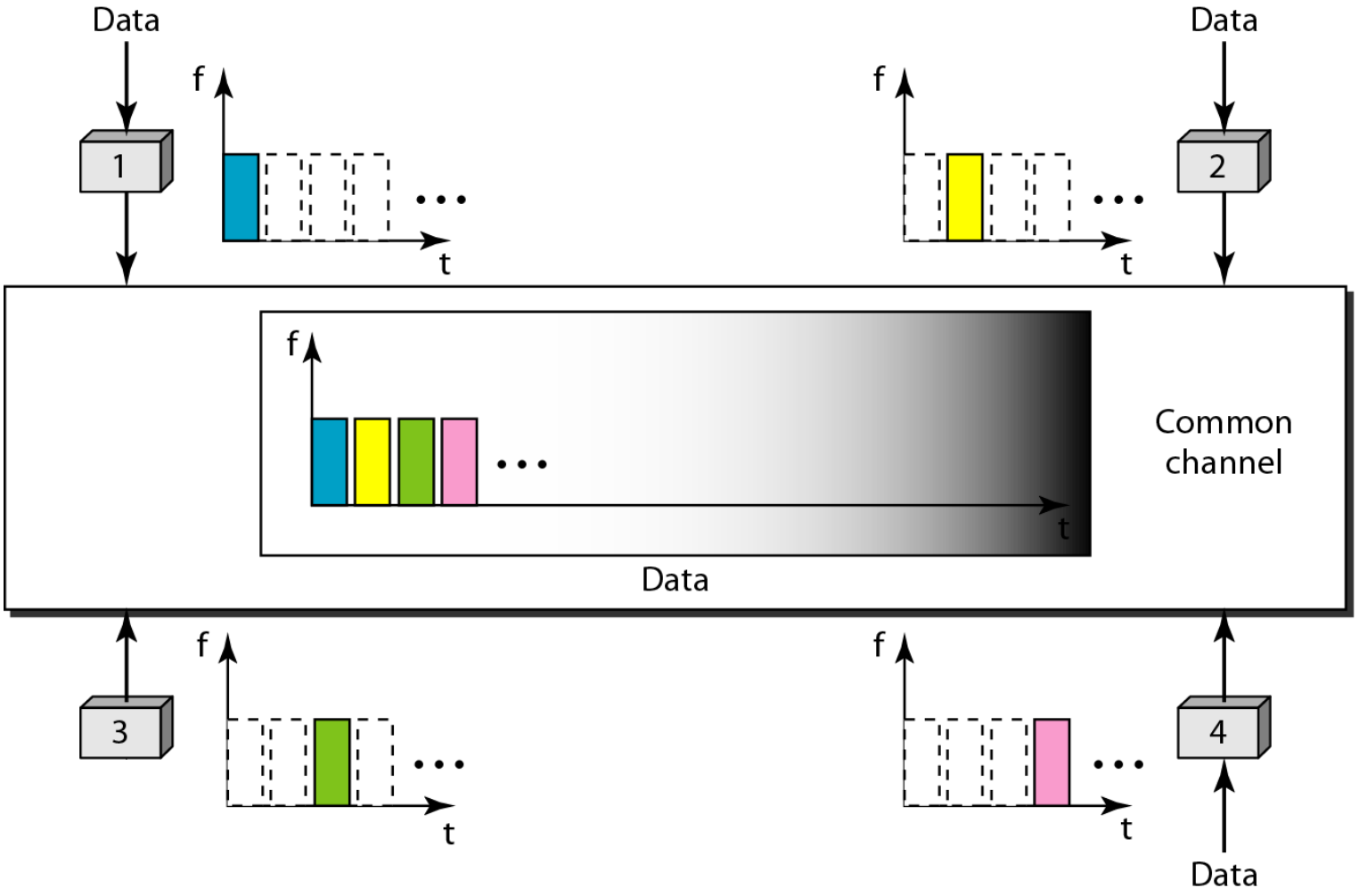
TIME-DIVISION MULTIPLE ACCESS (TDMA)

Under TDMA method, a channel is divided into time slots. Each slot is dedicated to different stations/users to transmit one byte or another digital segment.

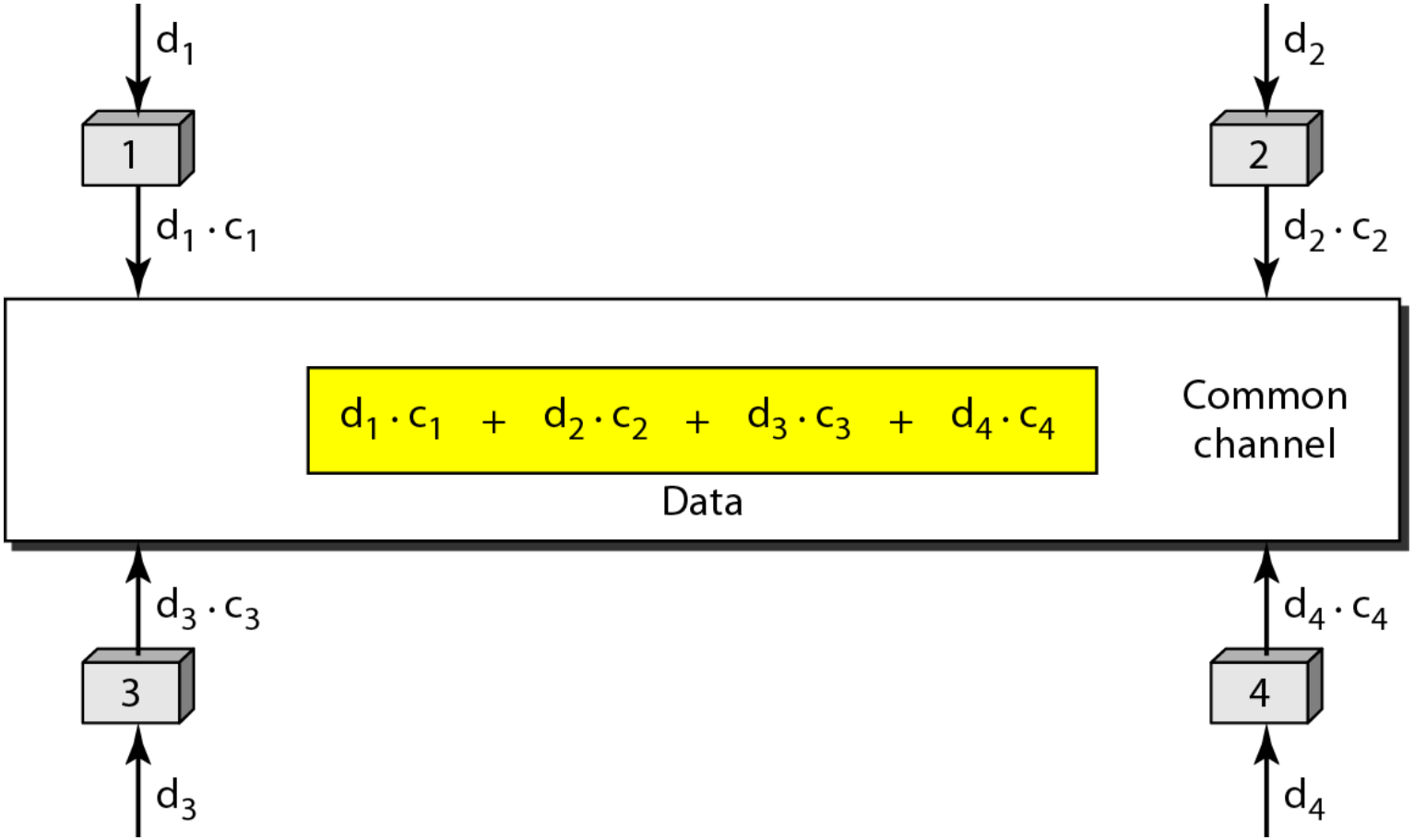


http://www.electronicdesign.com/communications/fundamentals-communications-access-technologies-fdma-tdma-cdma-ofdma-and-sdma

TDMA: EXAMPLE



CODE DIVISION MULTIPLE ACCESS



RANDOM ACCESS PROTOCOLS

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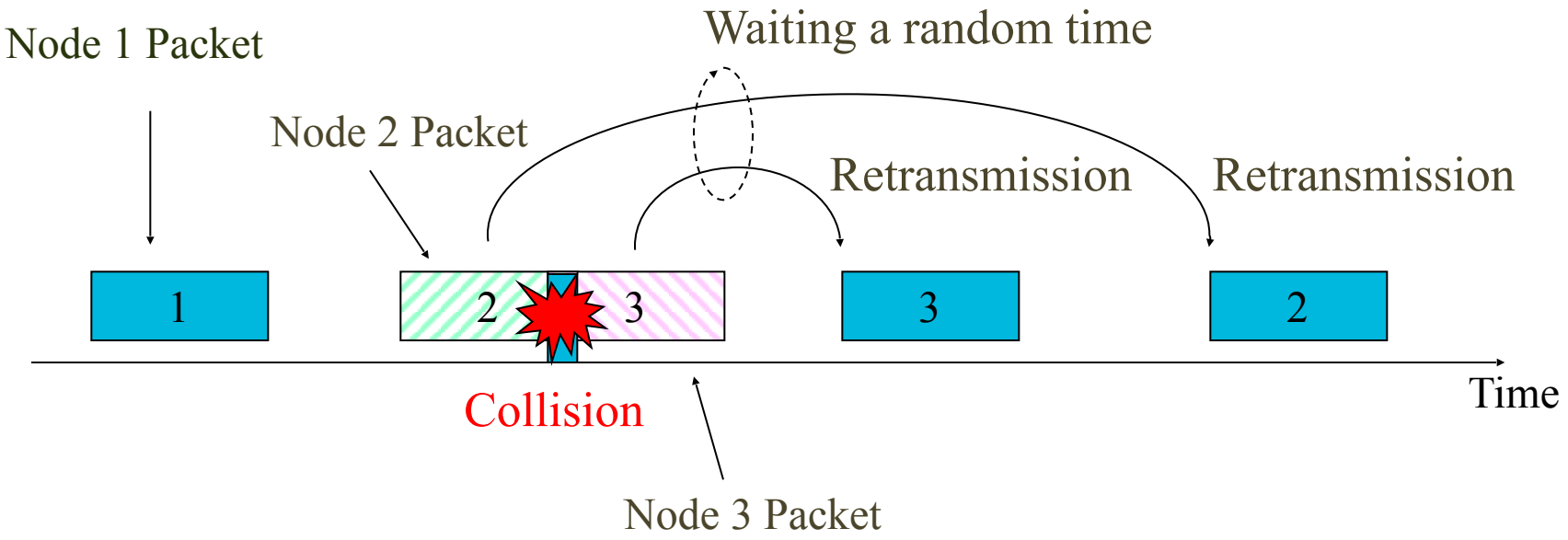
ALOHA

- ALOHA: Developed in the 1970s by Hawaii University
- Whenever a node has a packet, it transmits
- Transmitter listens the broadcast from the destination node, to check if the transmission was successful (or not)
- Sender retransmits after some random time if there is a collision
- Works well when traffic is very limited
- Unstable when the network is loaded

ALOHA: COLLISION EXAMPLE

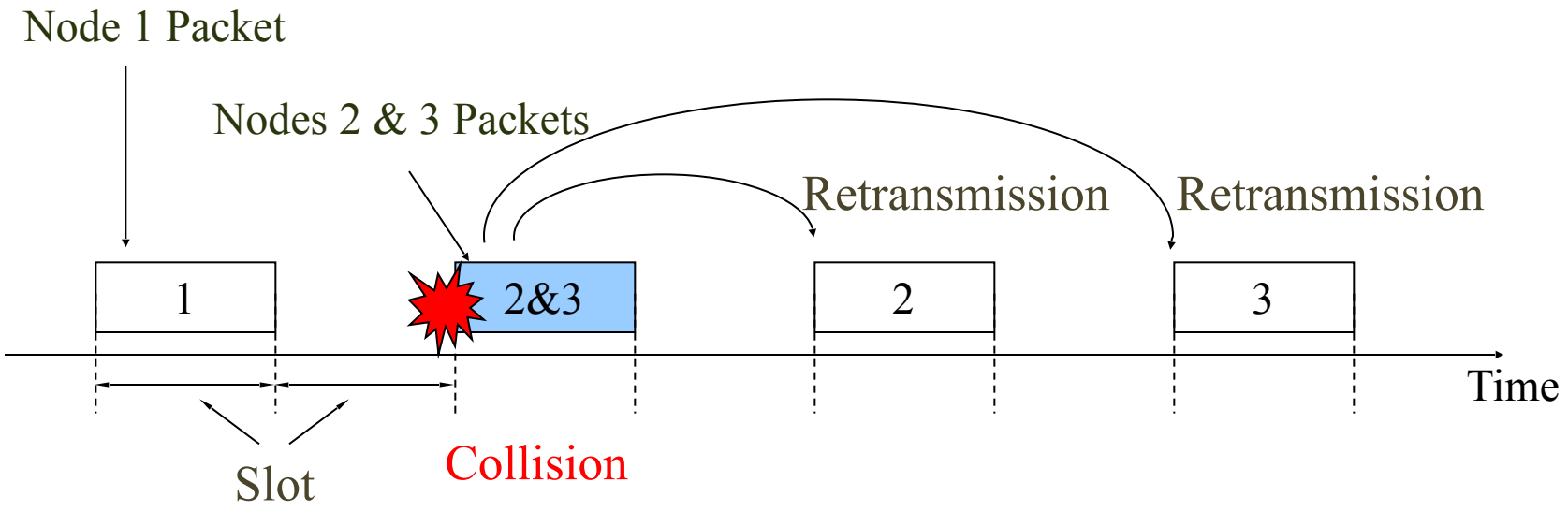


Collision mechanism in ALOHA

SLOTTED ALOHA

- Slotted ALOHA: *Time is slotted*
  - Transmission can take place only *at the beginning of slot*
  - Collision duration is reduced

SLOTTED ALOHA: COLLISION EXAMPLE



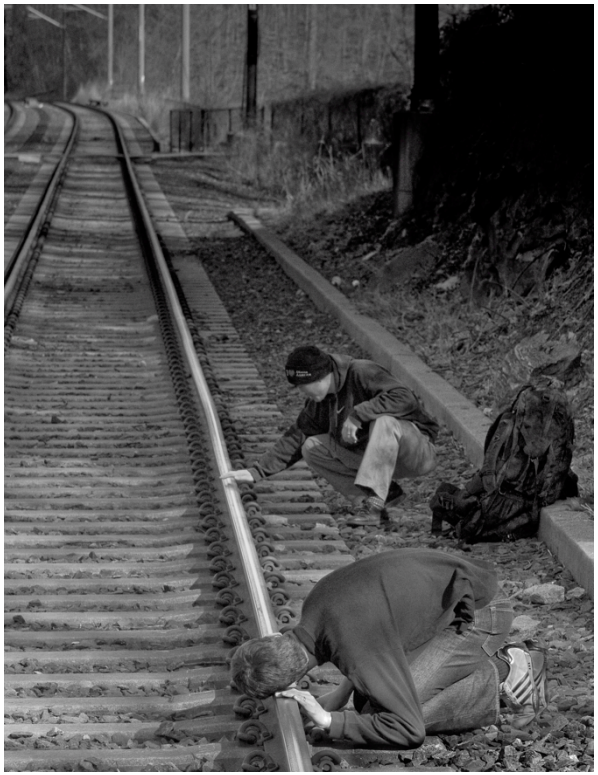
Collision mechanism in slotted ALOHA

CSMA (CARRIER SENSE MULTIPLE ACCESS)

- A node transmits only if no other transmission is ongoing
  - Listens to the channel before transmitting a packet

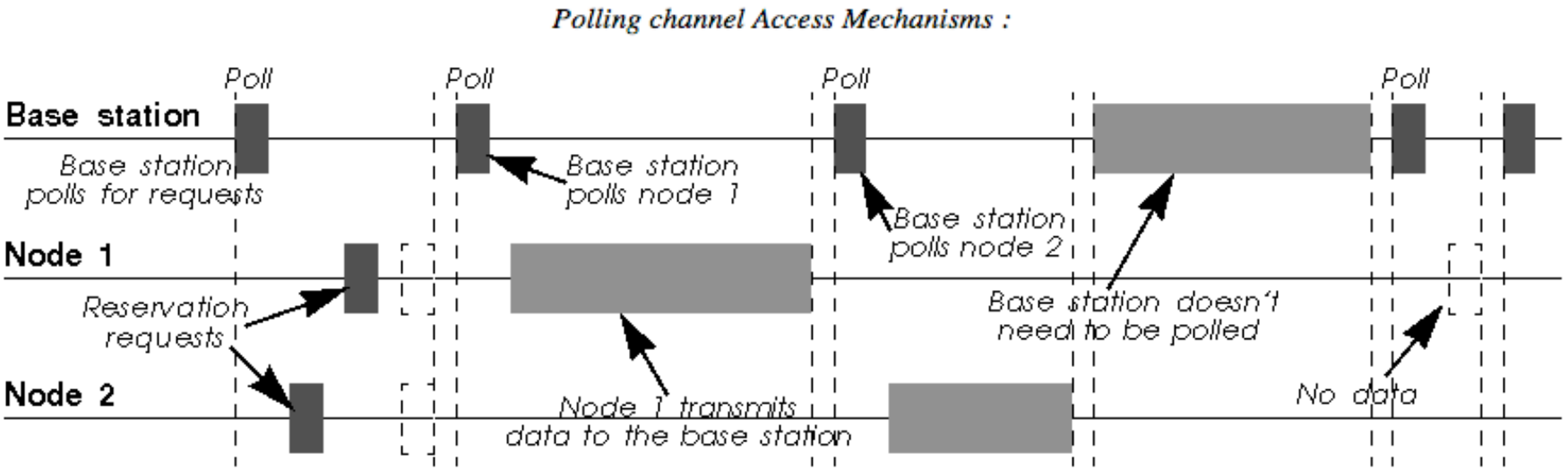
LISTENING (SAMPLING) THE MEDIUM

- Activity detection on the medium
- Clear Channel Assessment (CCA)
  - Detected energy > threshold
  - The detected signal corresponds to the PHY layer of the node with the same modulation and propagation characteristics



POLL

- Between TDMA and CSMA
- Base station control mechanism, with variable packets size, and a poll mechanism



Source: http://www.hpl.hp.com/personal/Jean_Tourrilhes/Linux/Linux.Wireless.mac.html

NOW HOW CAN YOU SLEEP?

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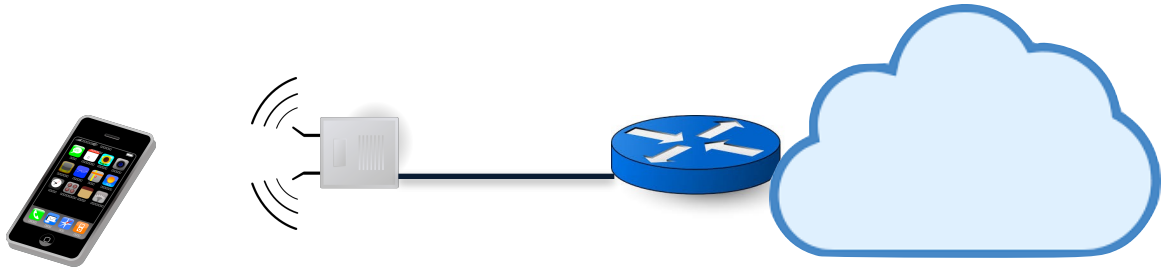
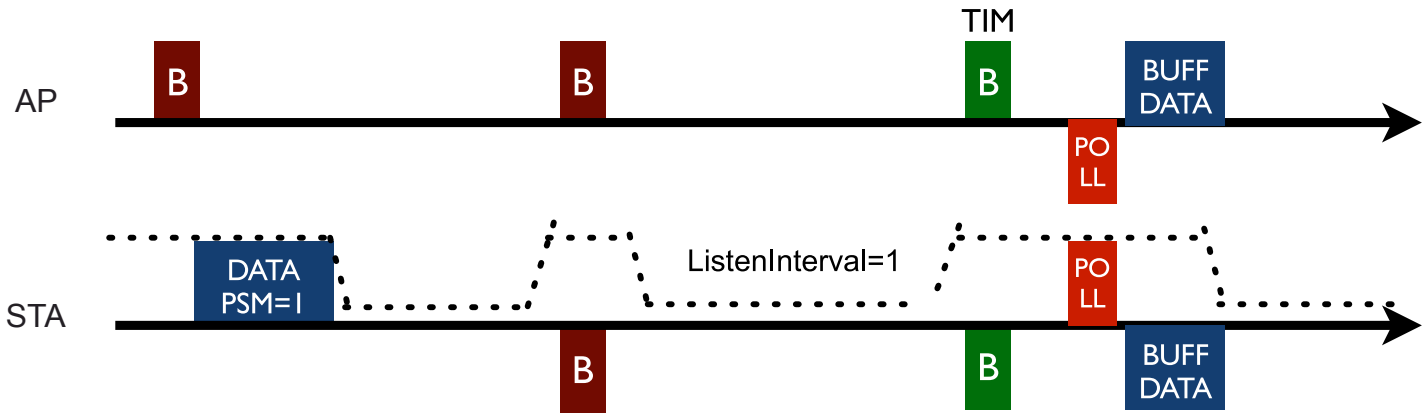
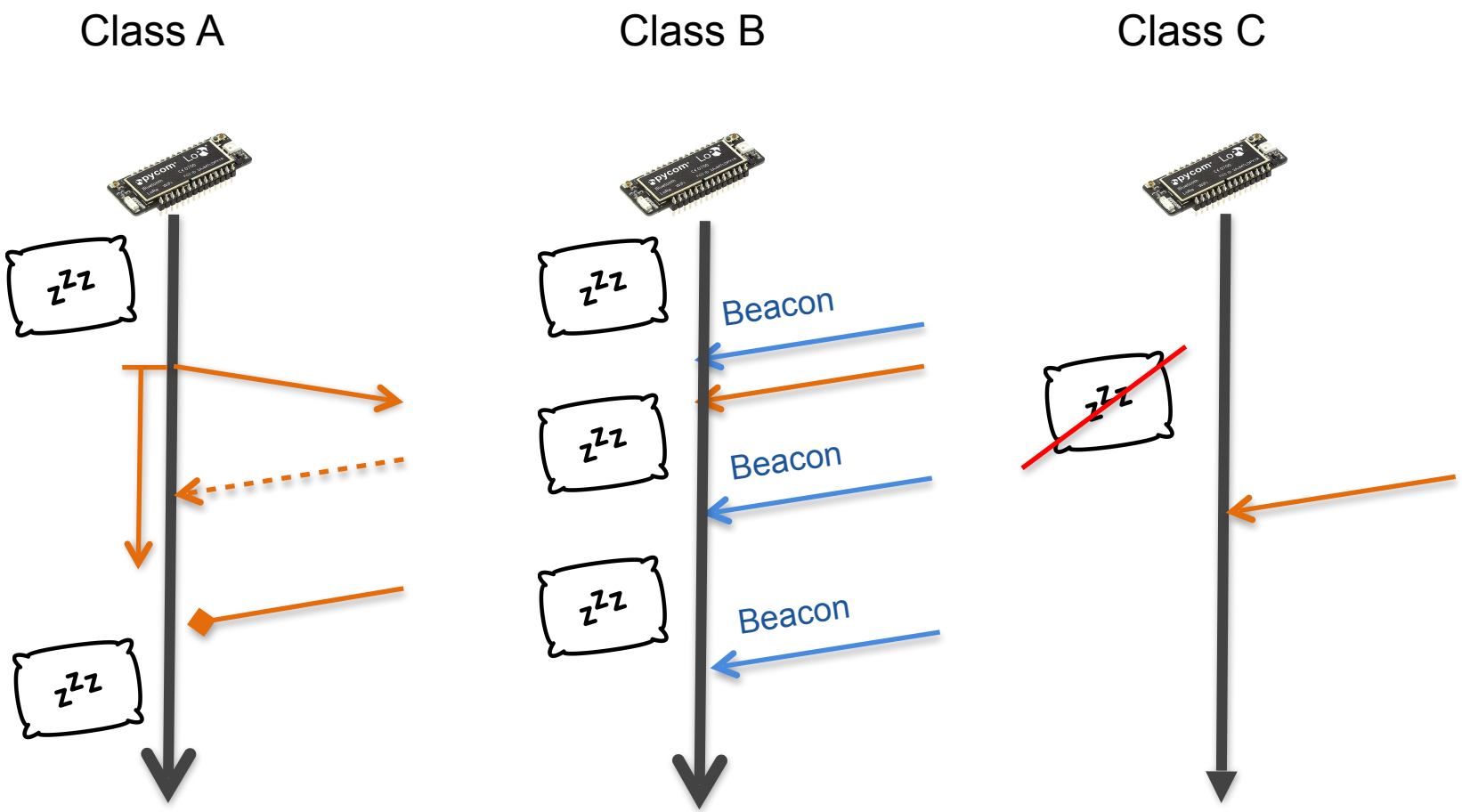
POWER SAVING MODE (INFRASTRUCTURE)

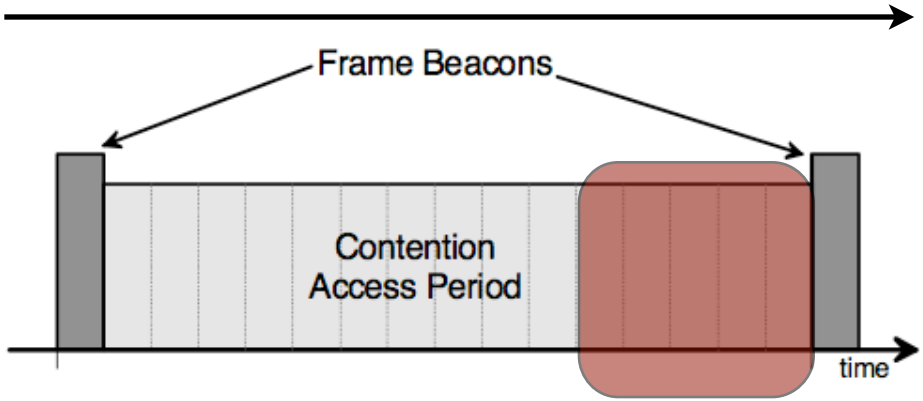




- MT actives the **PSM** bit in any frame (MAC header)
- It listens to some beacons and looks at TIM field
- It asks for buffered data (PS_POLL) and comes back to sleep

ASYMETRIC DEVICES

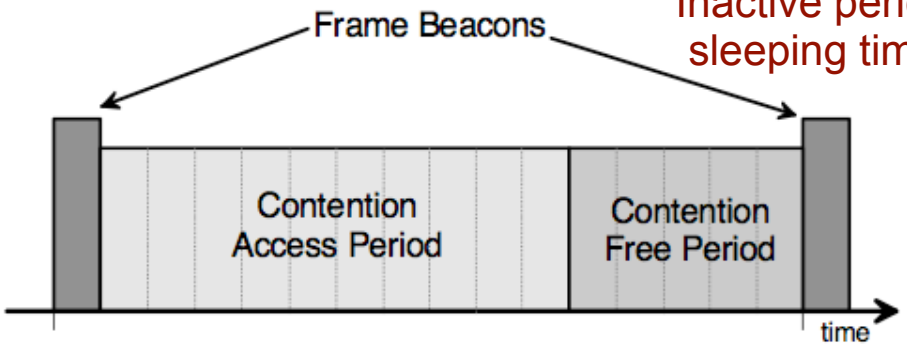




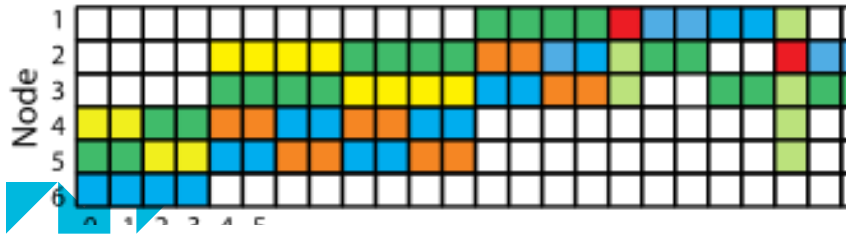
Beacon less - no synchronization

Beacon - Compete for the access (CSMA/CA)

Inactive period
sleeping time

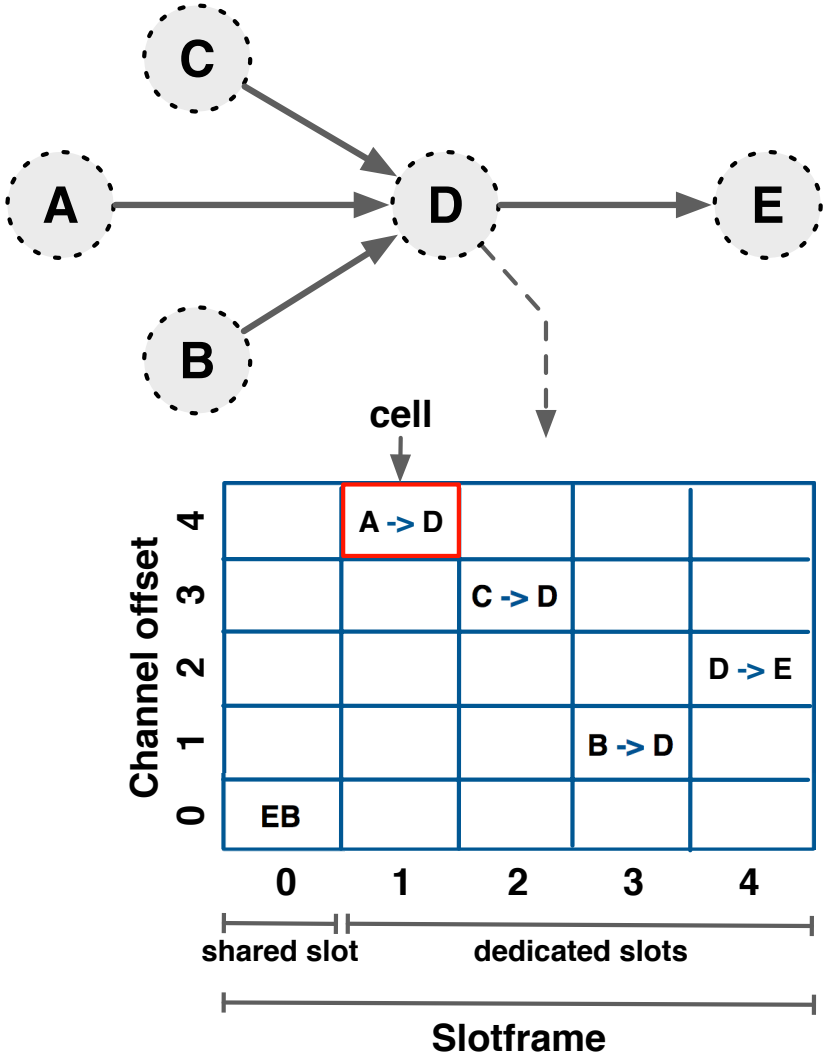


Beacon - Competition & guaranteed service (CSMA/CA and Poll)

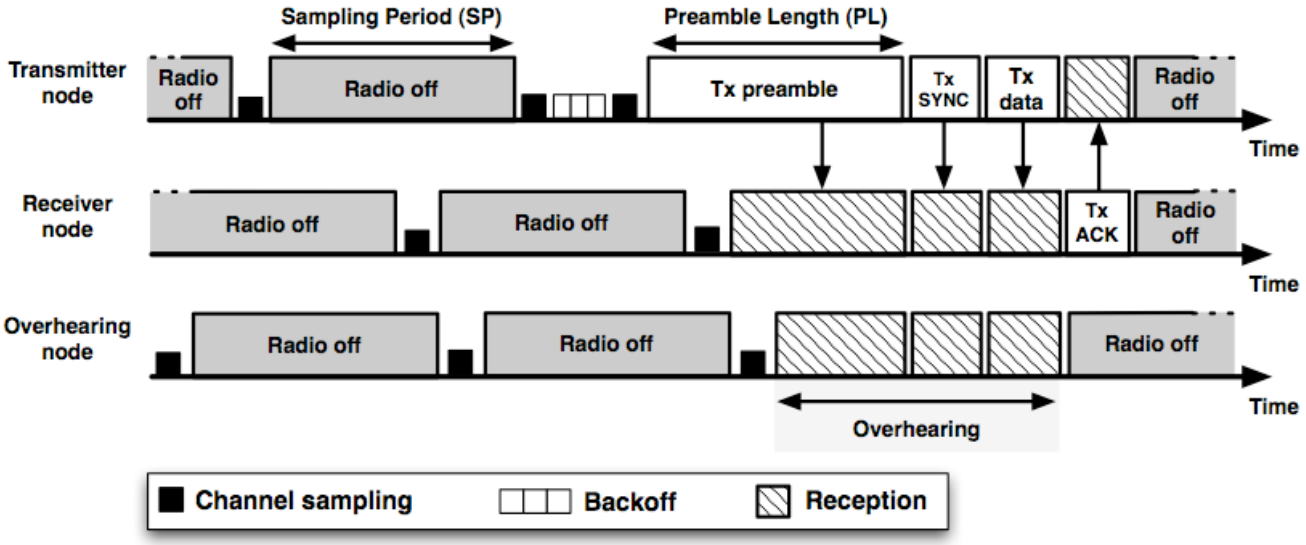


Time Slotted / Channel Hopping

IEEE 802.15.4 - TIME SLOTTED CHANNEL HOPPING



ADDITIONAL MECHANISM (NON STANDARDS)



Preambule MAC

ROUTING

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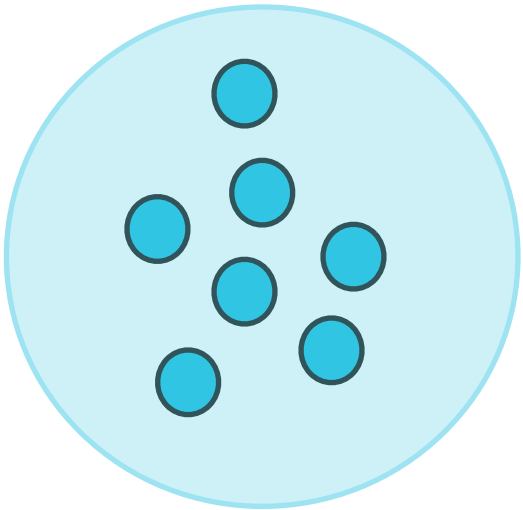
MULTI-HOP ROUTING

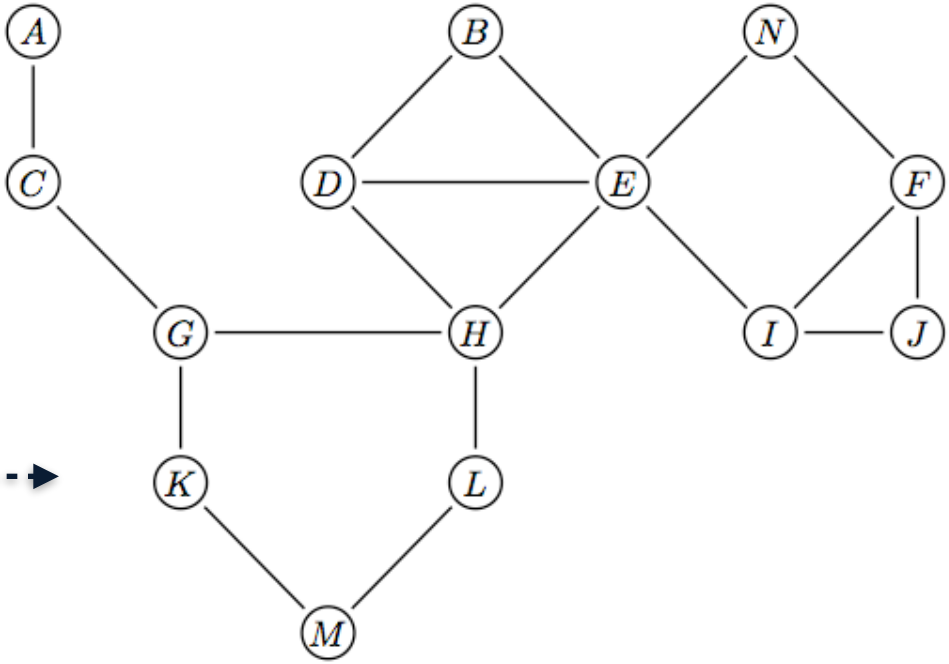
How to go to Trinitaine?

?

MULTI-HOP ROUTING



All nodes hear each others



Extended network area

Multi-hops: 2 principles

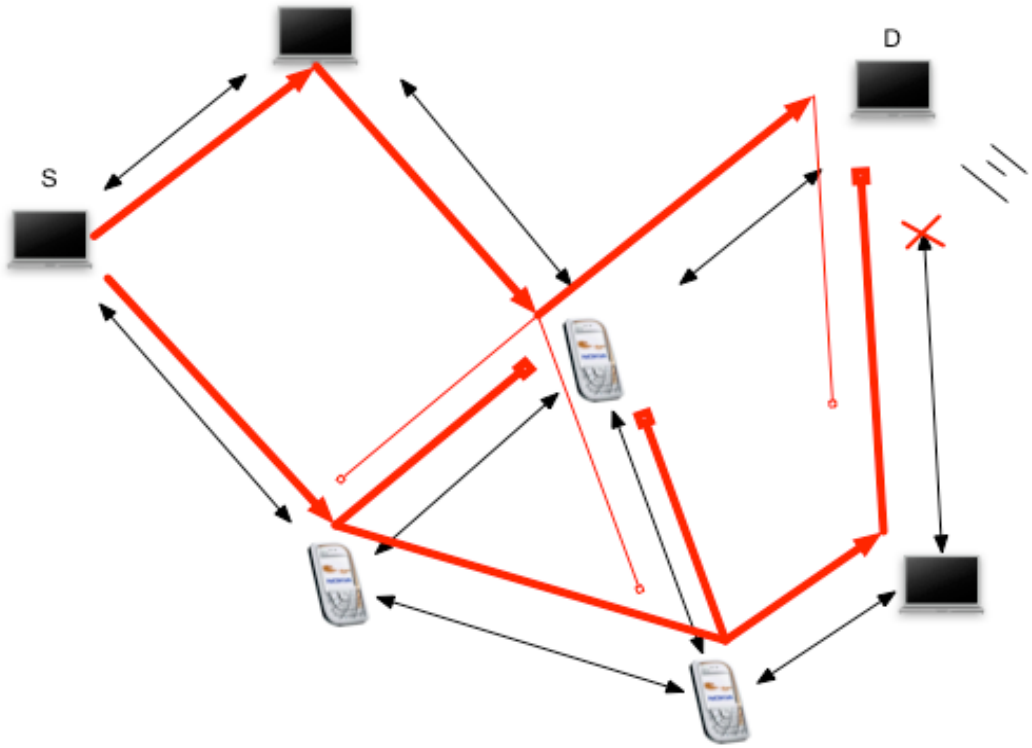
- **Routing**
  - Create and maintain the routes
  - Build a given vision of the topology
  - Objectives
    - Minimum signalling
    - No loops
    - Quick convergence
    - Take into account the link variability
    - energy consumption
- **Forwarding process**
  - Retransmission toward the destination

MECHANISMS (1/2)

- **Neighbor discovery**
  - Periodically send a (one-hop) signaling message

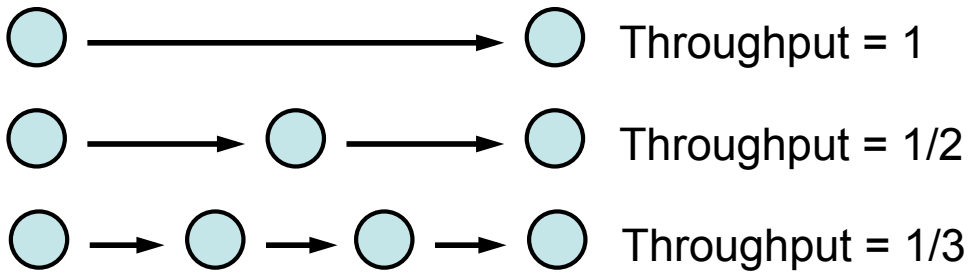
MECHANISMS (2/2)

- **Flooding**
  - Flood the network with a signaling information
  - Learn and build the routes

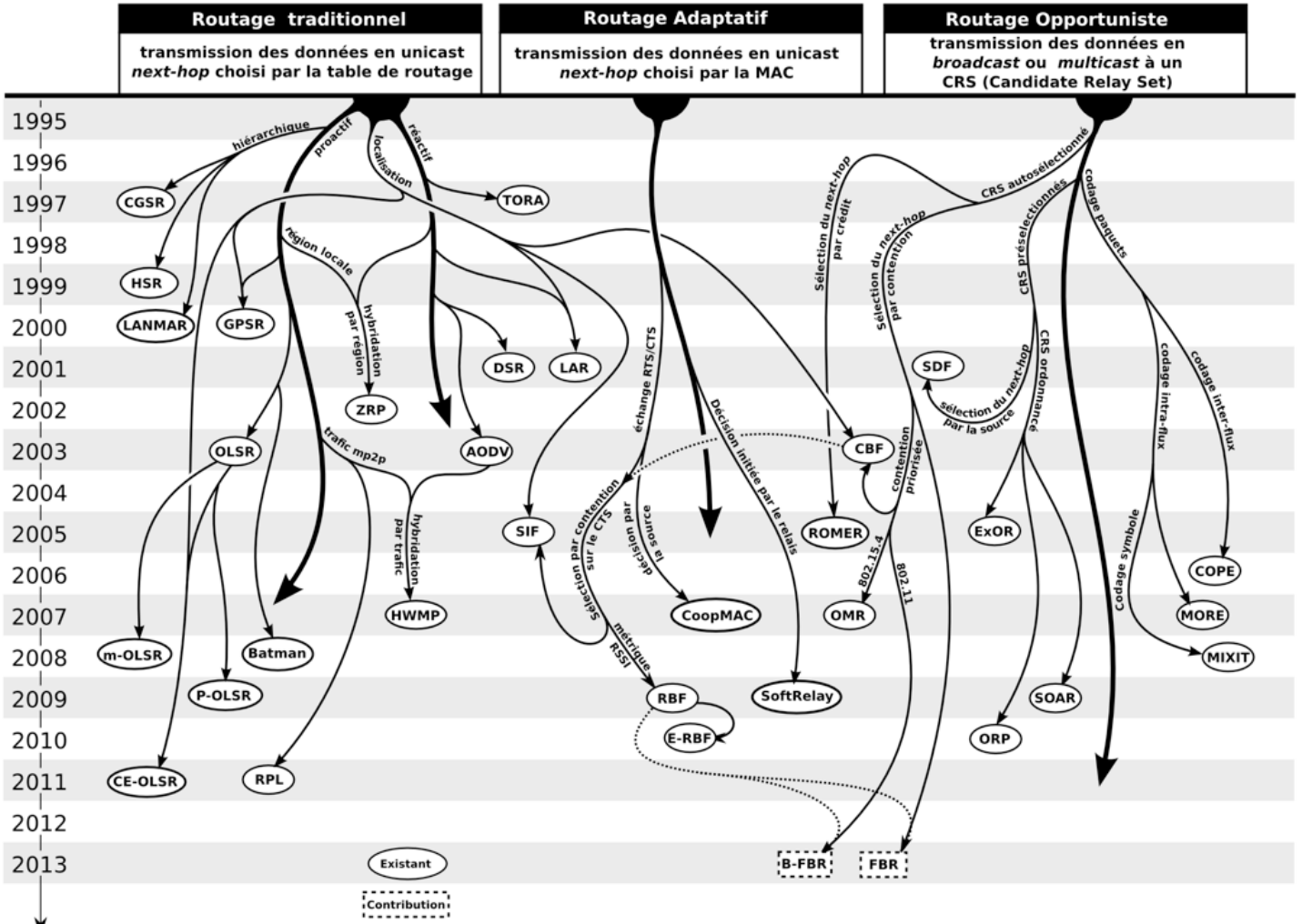


METRICS

- **How do you select a route / a neighbor**
  - End-to-end
    - Hop count
    - Packet Delivery ratio
    - Delay
    - throughput
    - Energy consumption
  - Hop-by-hop
    - Expected Transmission Time (ETT)
    - Expected Transmission Count (ETX)
    - Energy consumption



CLASSIFICATION



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By Lucien Loiseau

LRI SA

PROACTIVE VS. REACTIVE

- Proactive
  - Traditional distributed shortest-path protocols
  - Based on periodic updates
  - High routing overhead

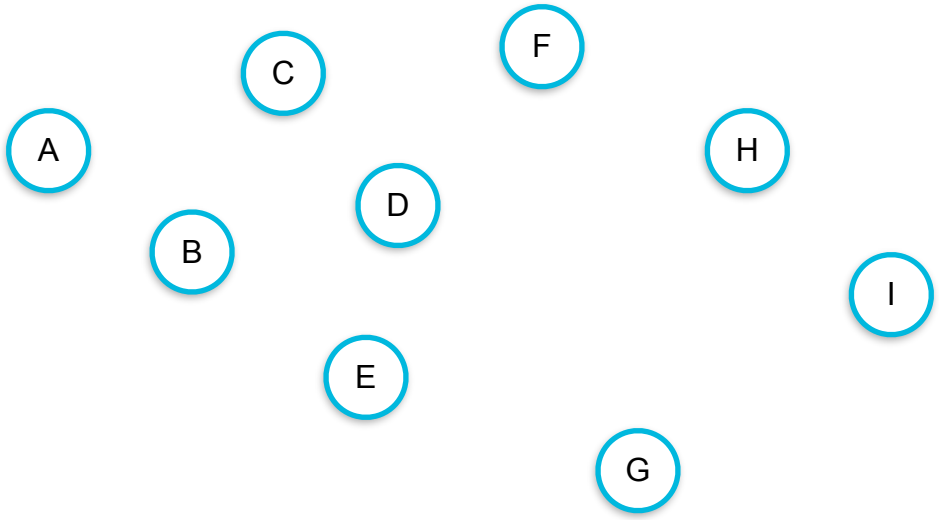
Vs.

- Reactive (On-demand) protocols
  - Discover routes when needed
  - Source-initiated route discovery

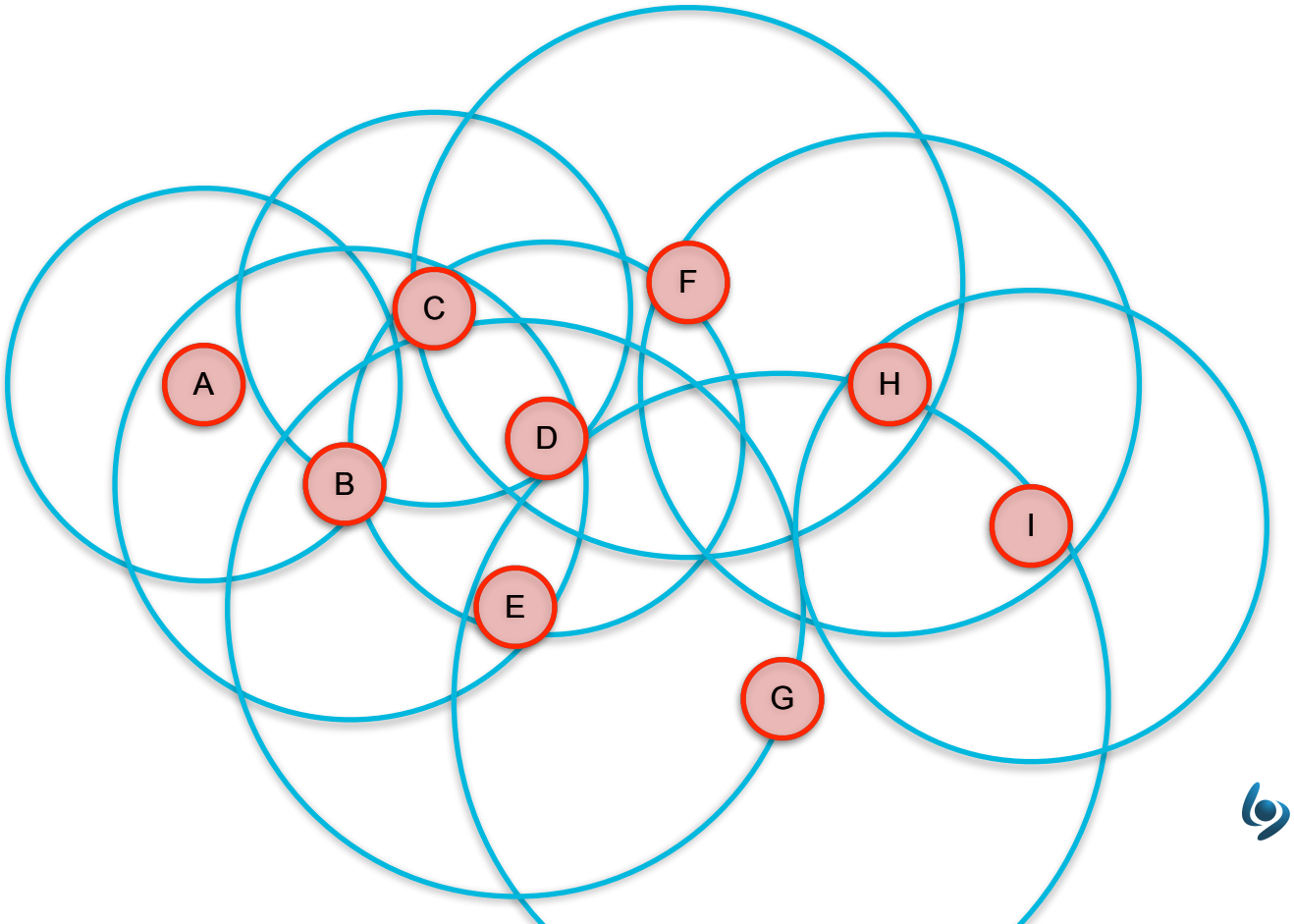
- Tradeoff
  - State maintenance traffic vs. route discovery traffic
  - Route via maintained route vs. delay for route discovery

LOADng (reactive protocol)

1. Flood a Route Request



1. Flood a Route Request



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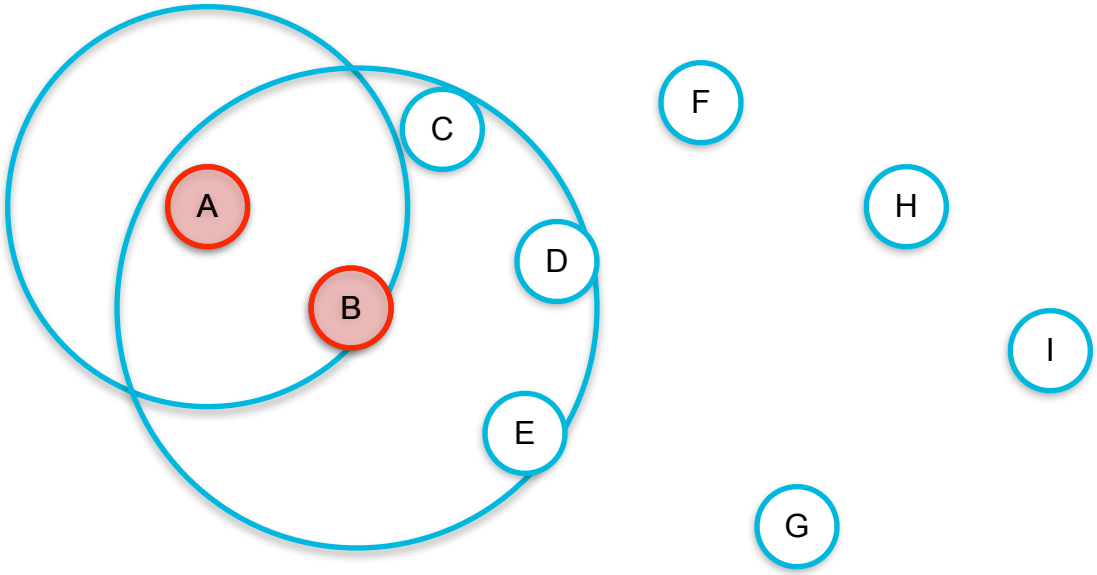
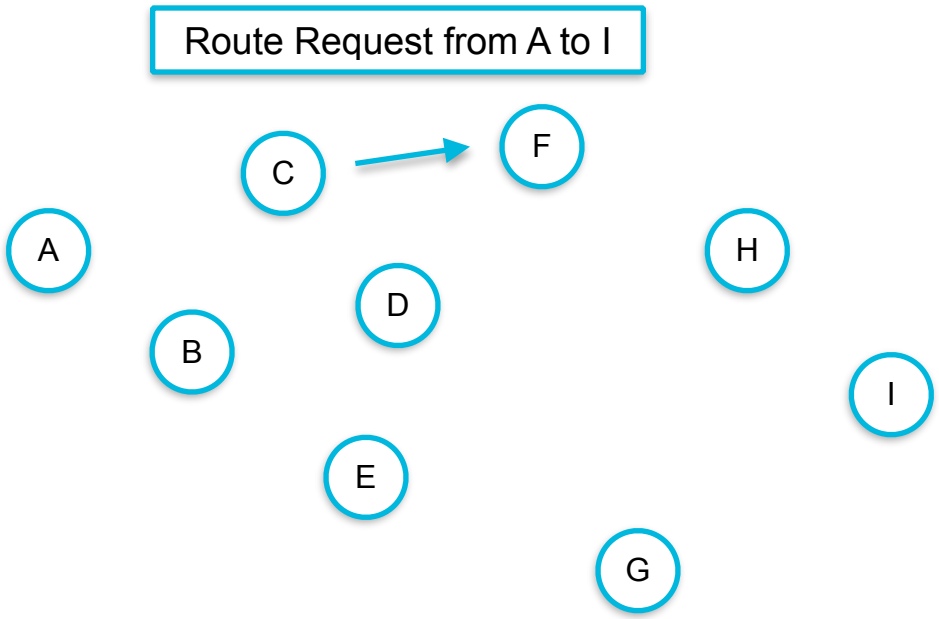


LOADng

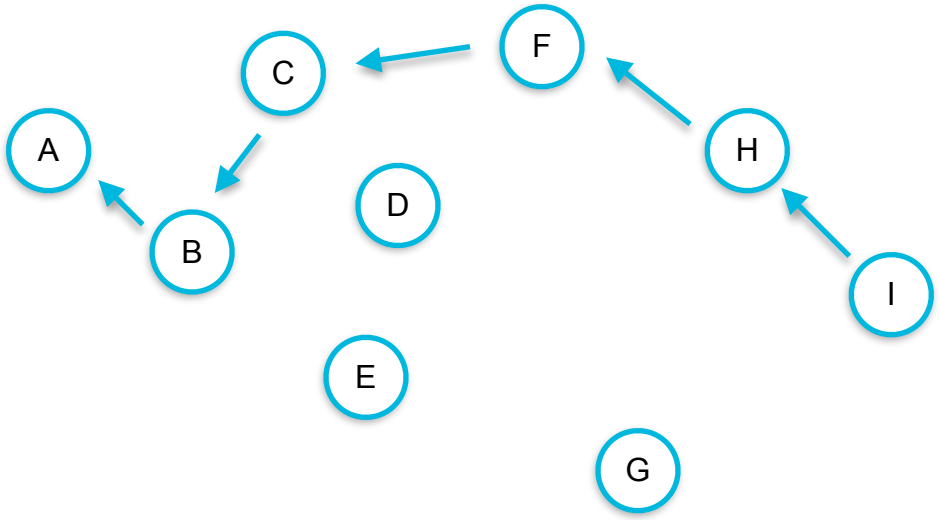
F Routing Table

Dest.	Next Hop	Dest Seq N.	Hops	Lifetime
A	C	4	3	100
C	*	10	0	100



LOADng

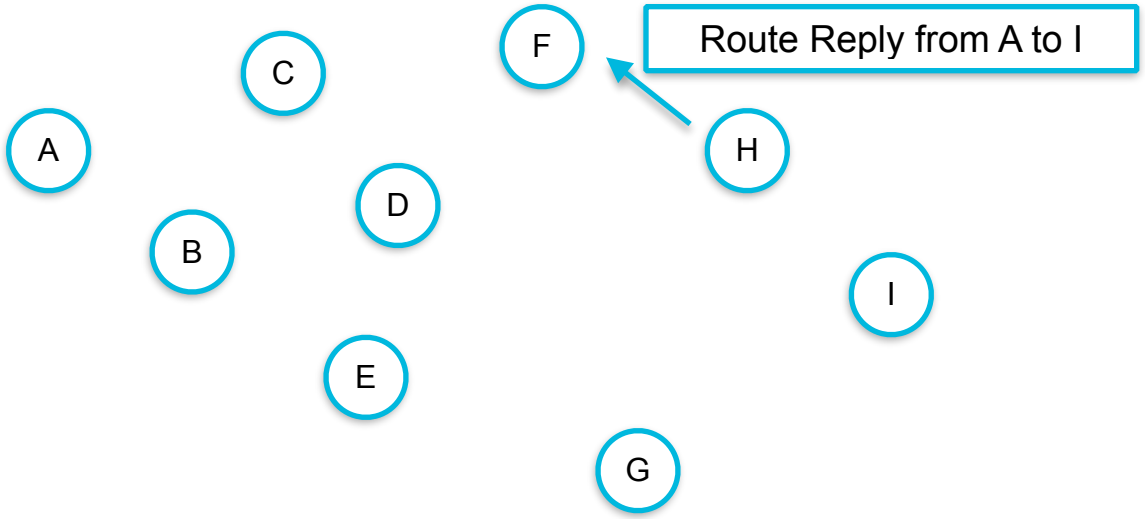
1. Flood a Route Request
2. Respond with a Route Reply



LOADng

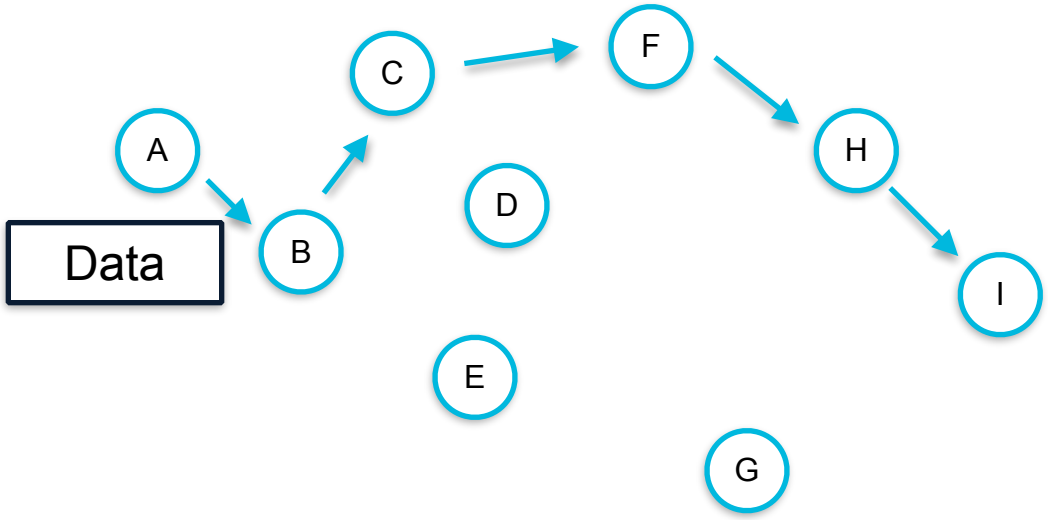
F Routing Table

Dest.	Next Hop	Dest Seq N.	Hops	Lifetime
A	C	4	3	99
C	*	10	0	99
I	H	6	2	100



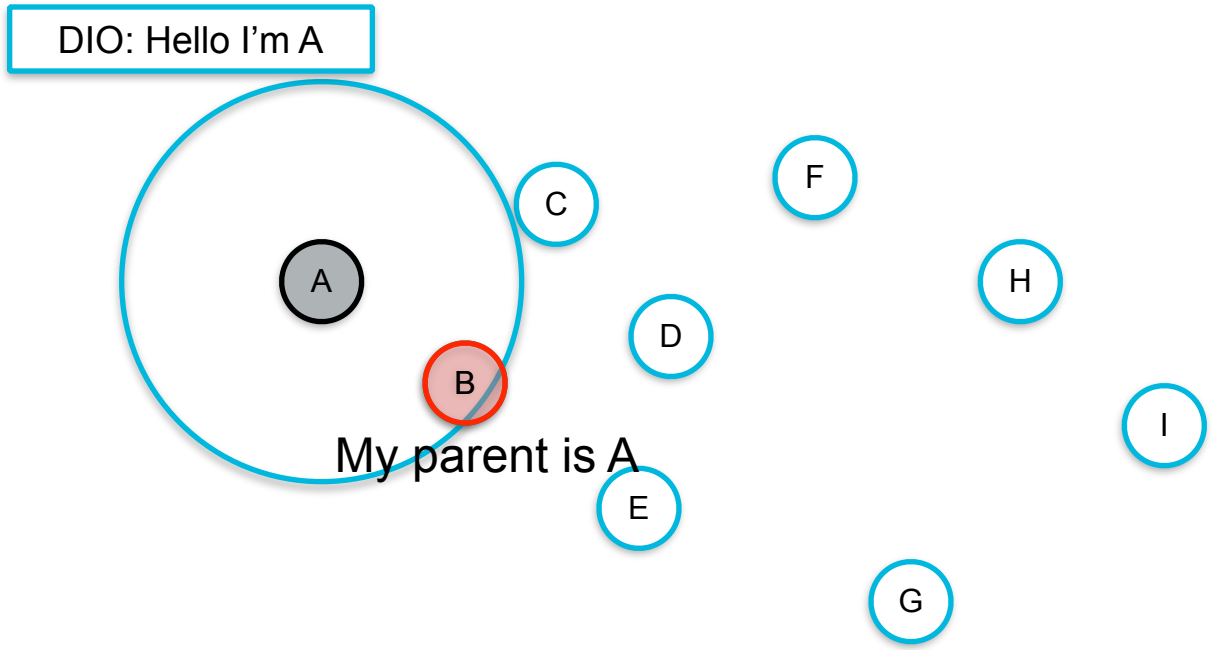
LOADng

1. Flood a Route Request
2. Respond with a Route Reply
3. Send your data



A is the root node.

1. Send DIO



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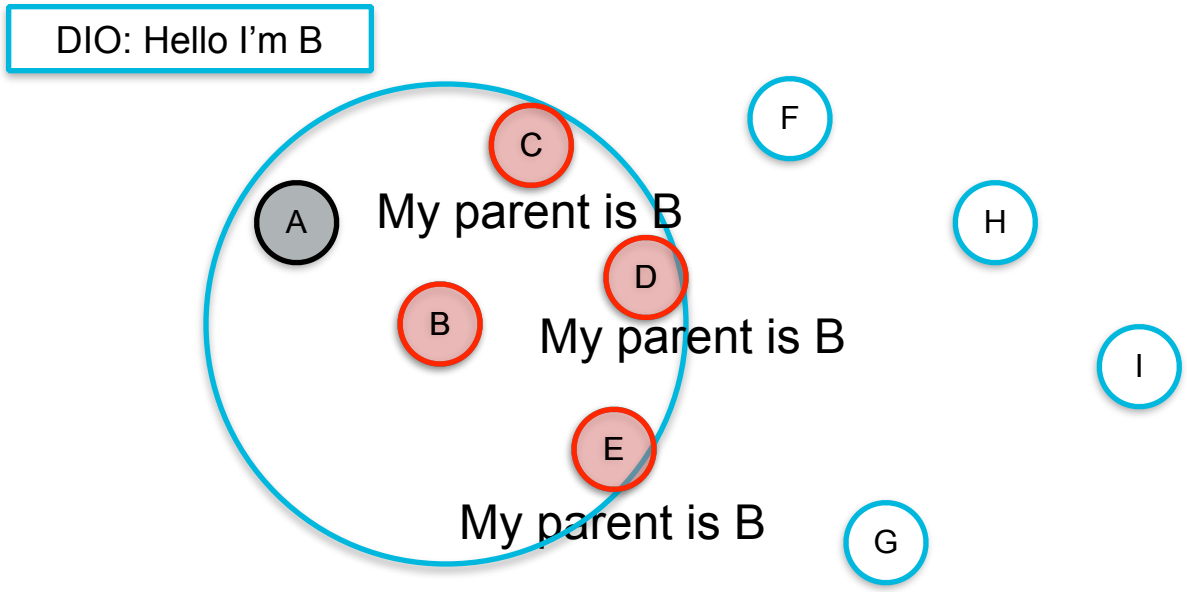

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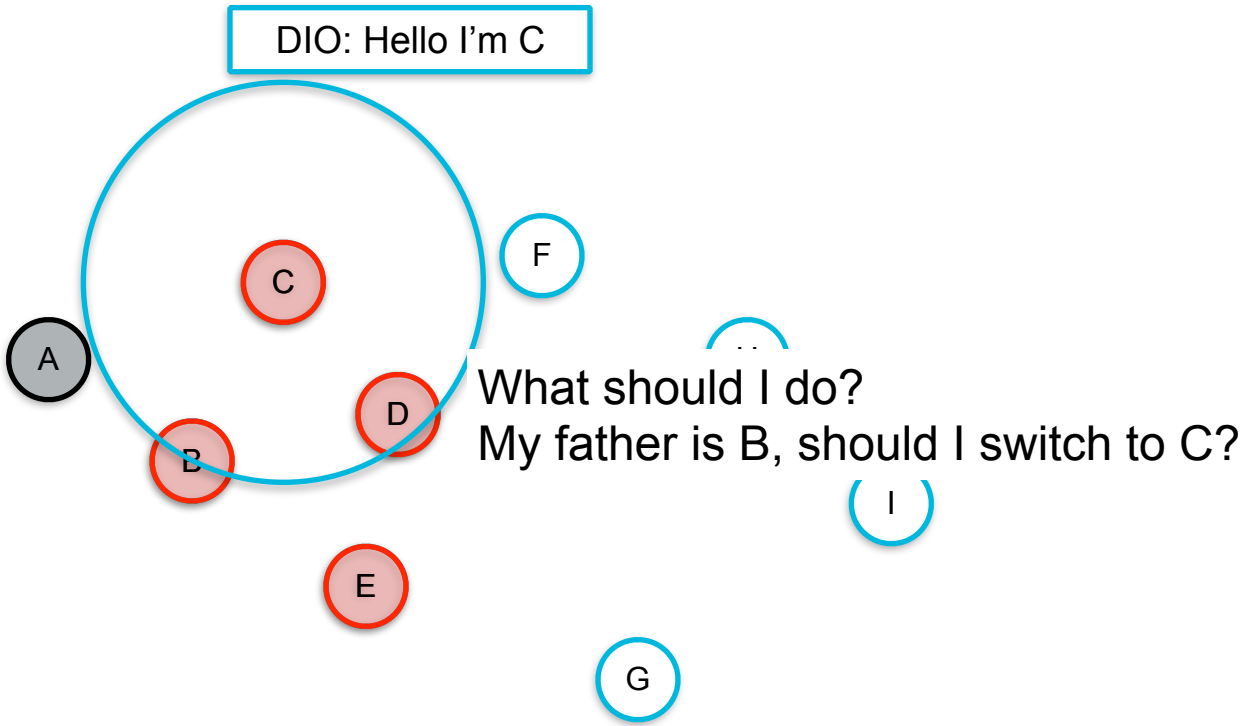
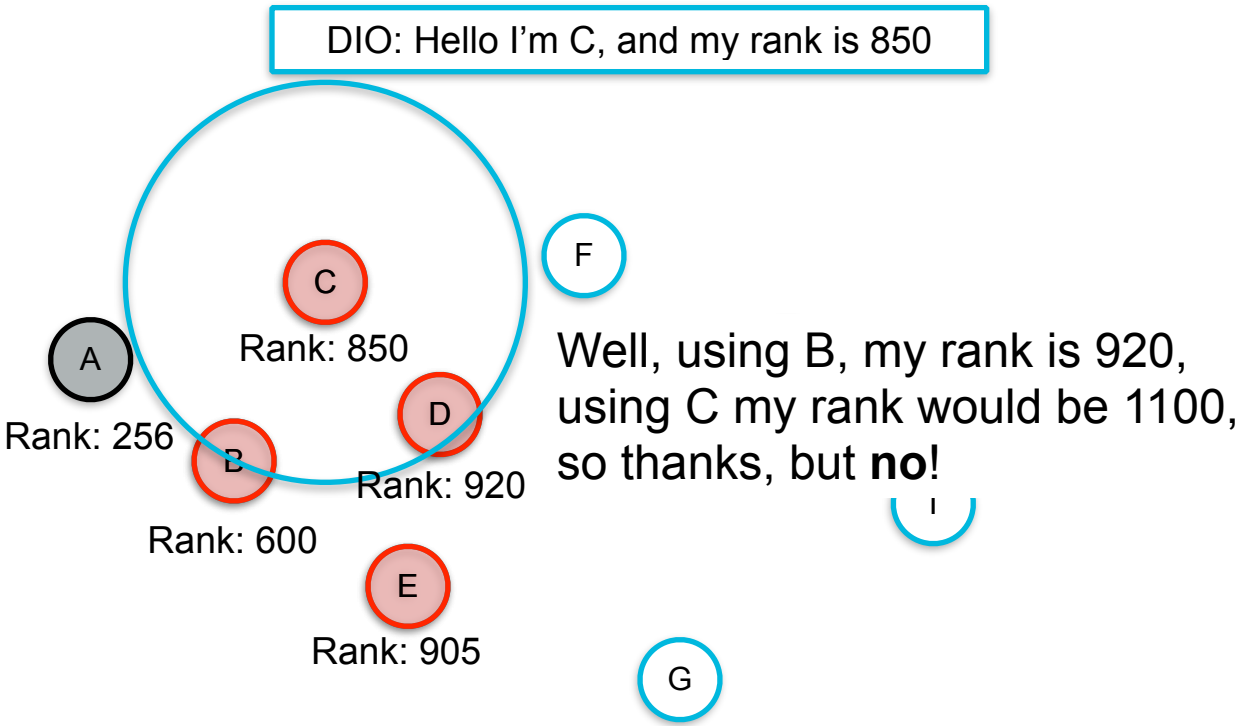


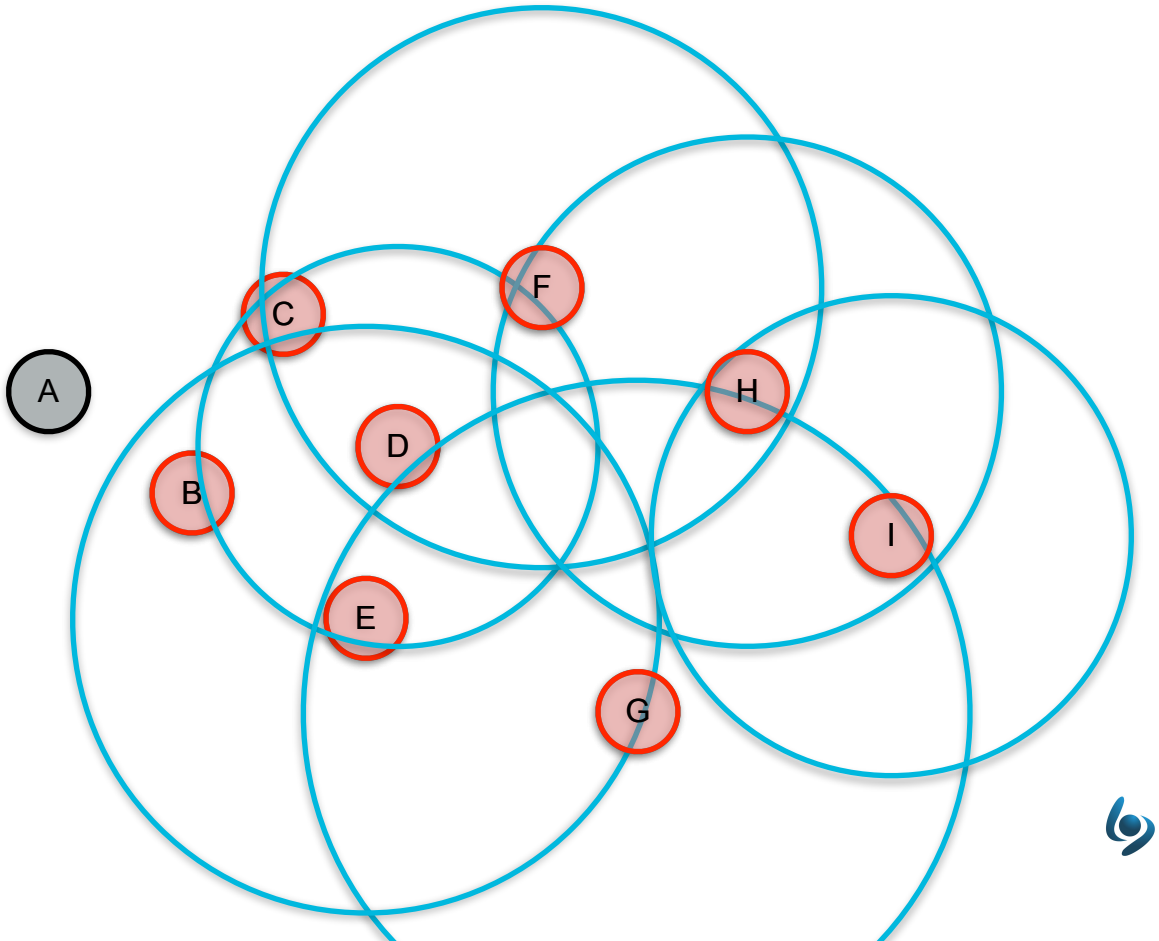
A is the root node.

1. Send DIO



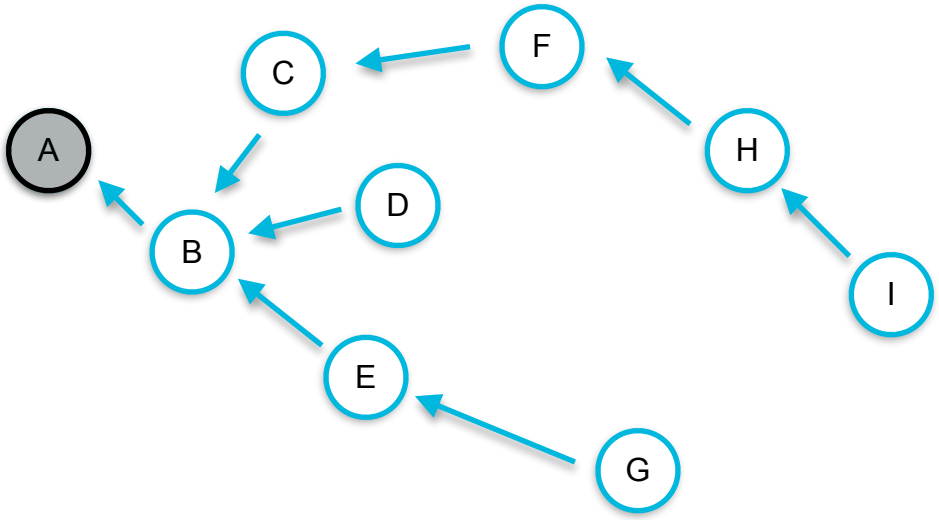
A is the root node.

1. Send DIO



A is the root node.

1. Send DIO
2. Build a Destination Oriented Directed Acyclic Graph

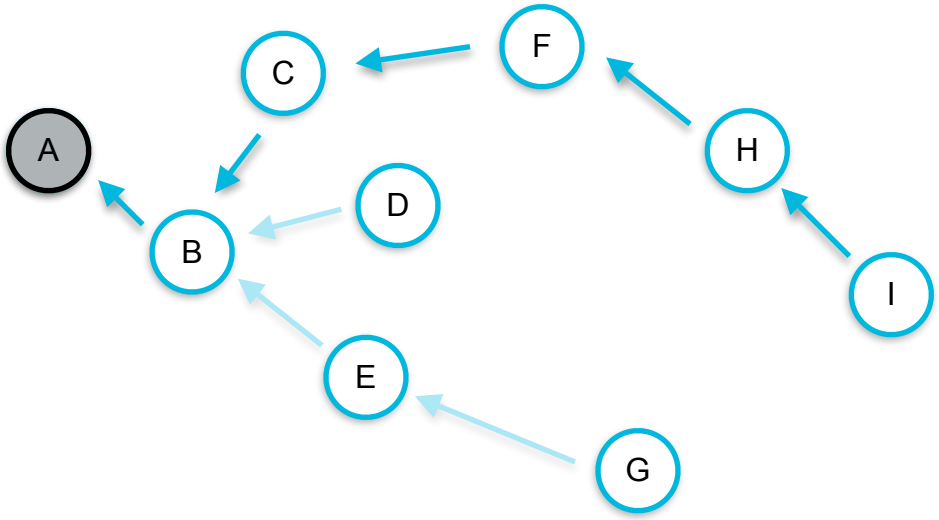


RPL

A is the root node.

1. Send DIO
2. Build a Destination Oriented Directed Acyclic Graph
3. Send data

Just send to your parent!

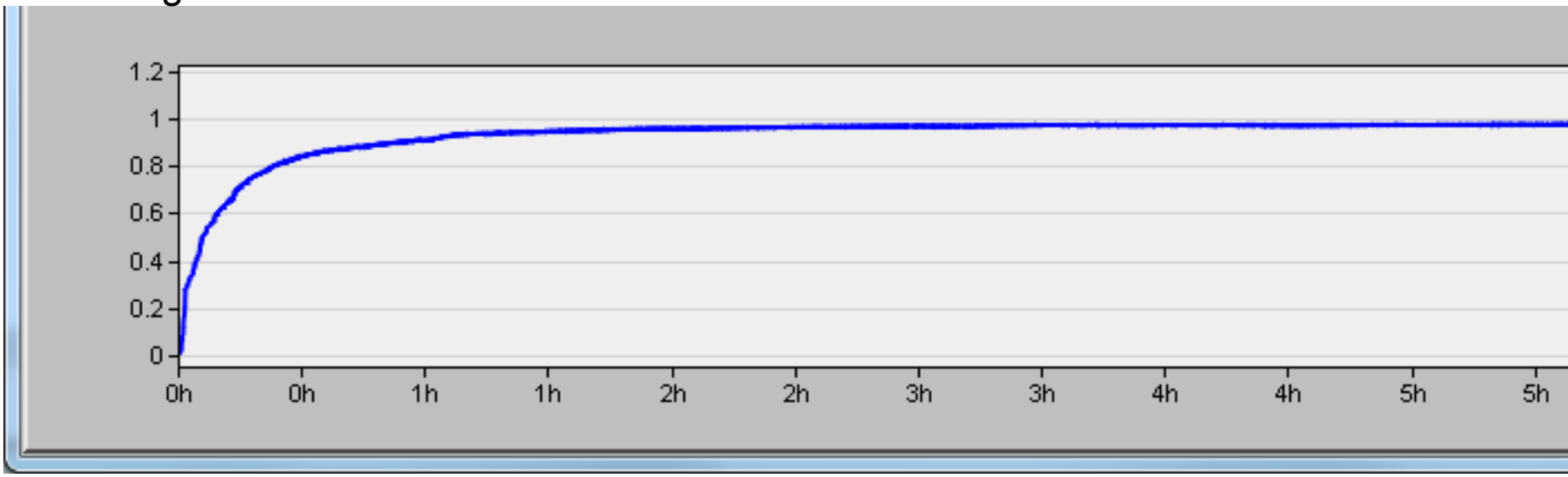


So which one do you prefer?

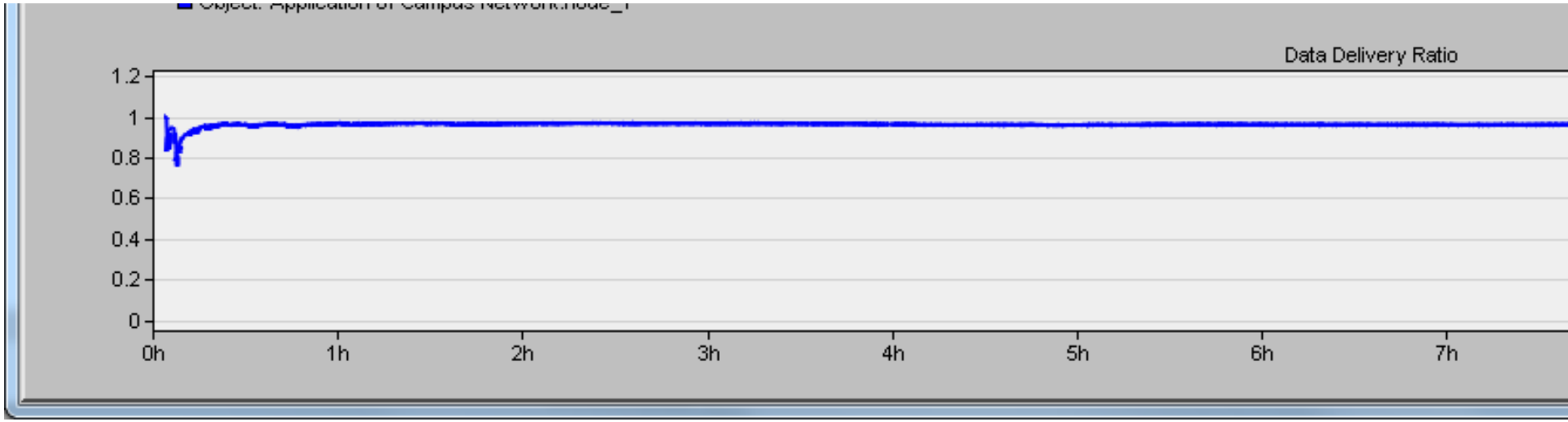
Vs

LOADng vs RPL: Packet Delivery Ratio

LOADng

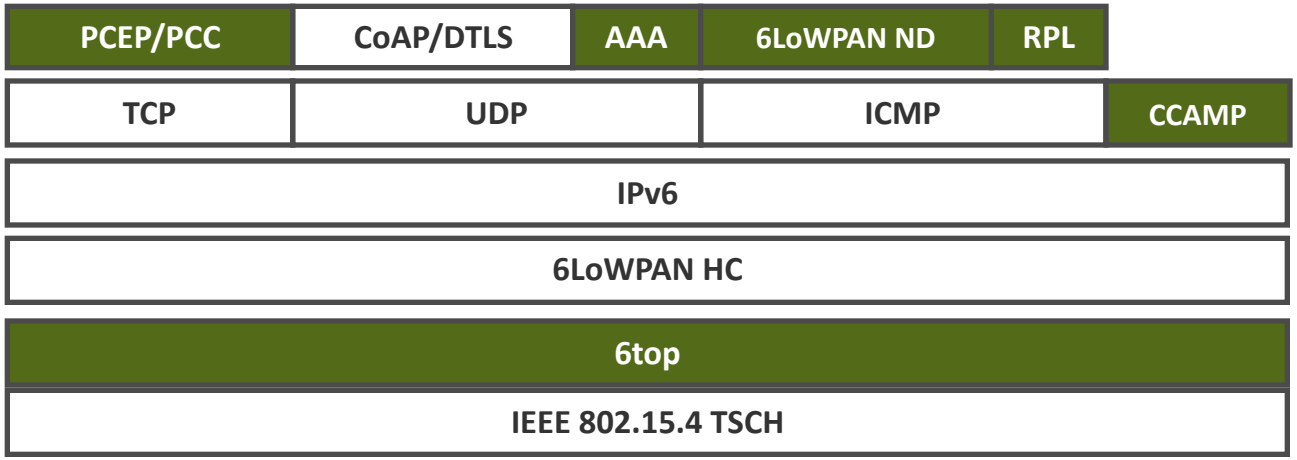


RPL



CONCLUSION

IoT stack



Energy saving =>

Avoid verticals, but still many different applications

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