REAL-TIME NETWORKS

Recapitulation

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Wired networks covered

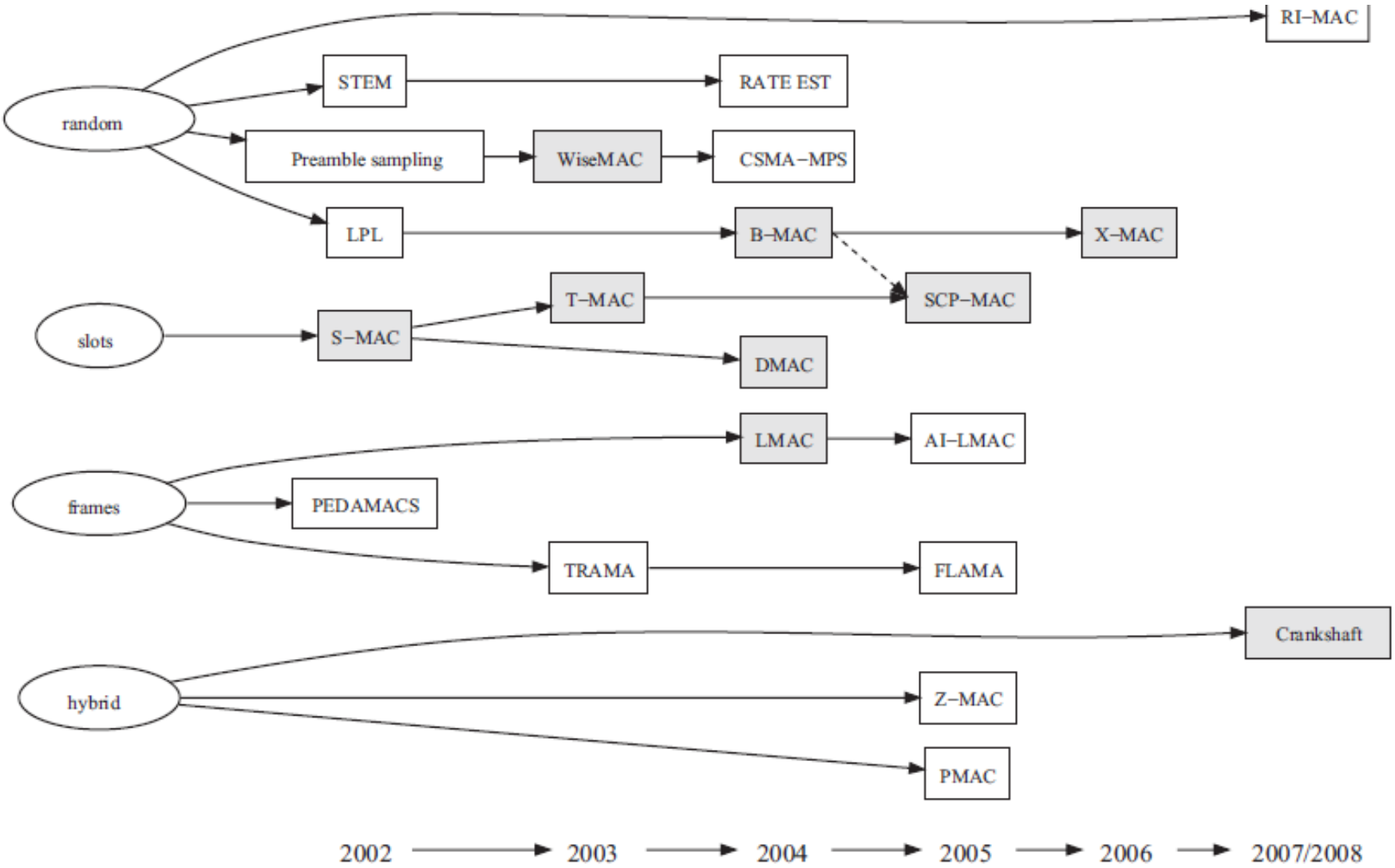
- CAN
- WorldFIP
- Ethernet
  - “pure”
  - Additional rules (e.g. traffic shaping)
  - Additional MAC

Wired Networks

- Most of the real-time properties at MAC level
- Do not forget inaccessibility
- The higher the line speed, the higher the overhead of request/response protocols
- Switched networks are able to exploit both directions simultaneously

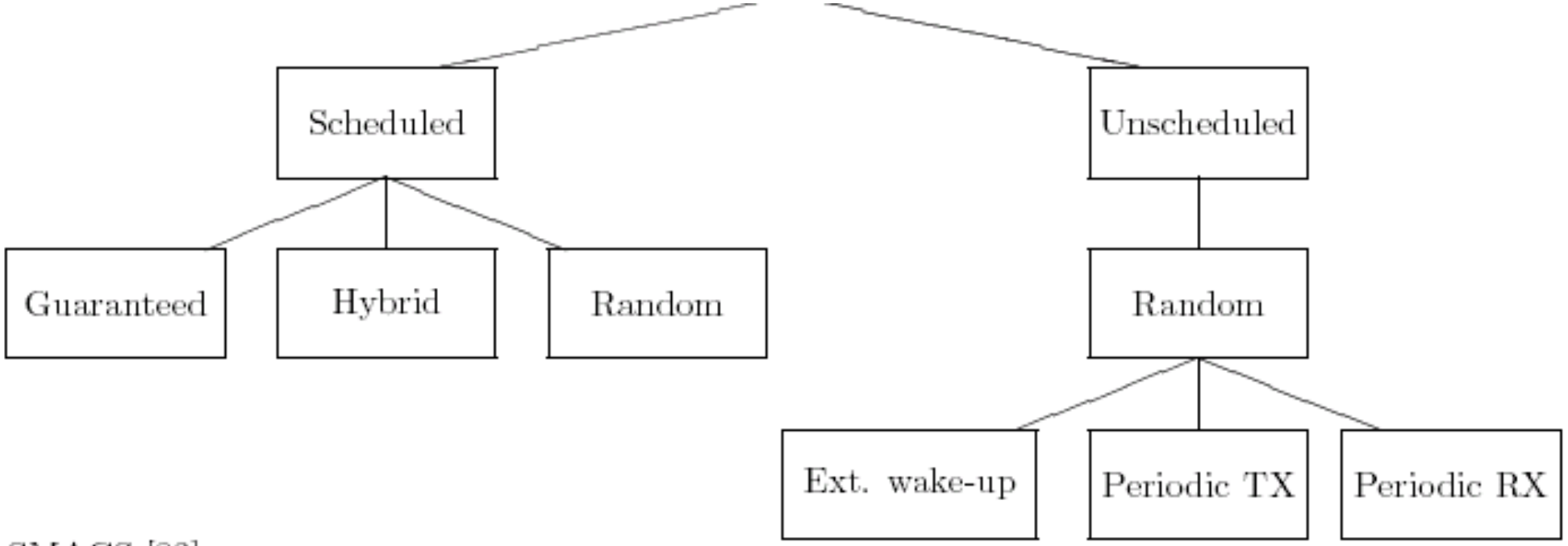
- Time Sensitive Networking (TSN) is the current effort to make Ethernet real-time

Wireless sensor networks



Source K. Langendoen and A. Meier. « Analyzing MAC protocols for low data-rate applications ». *ACM Trans. Sen. Netw.* 7, 1, Article 10 (August 2010)

Another WSN taxonomy



SMACS [83]
LEACH [36]
PACT [65]
BMA [51]
BitMAC [73]

EMAC [92]
LMAC [93]

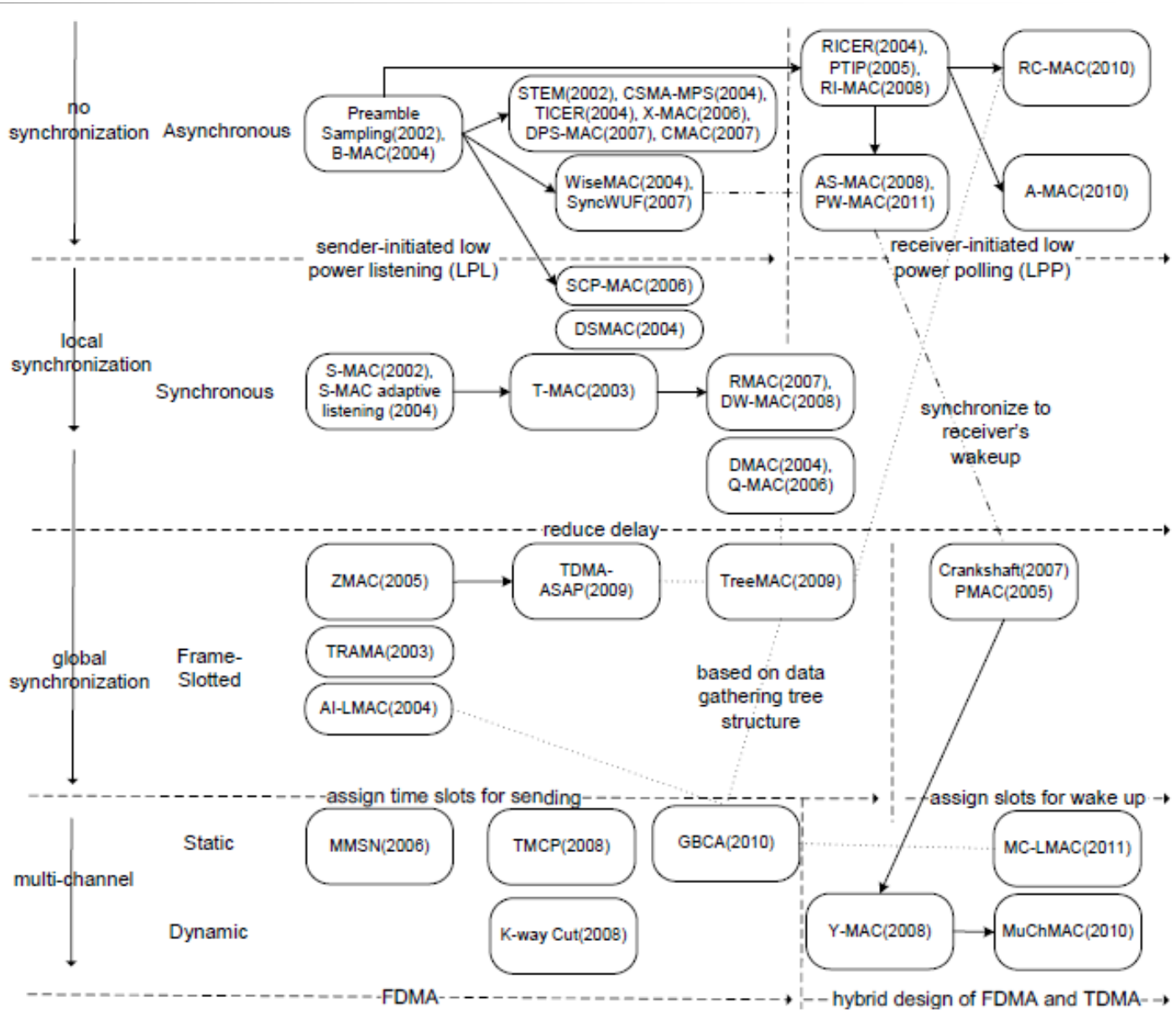
S-MAC [99]
T-MAC [90]
D-MAC [53]

PicoRadio [70]

RI-MAC,
802.15.4e

BMAC
WiseMAC
X-MAC….

More recent survey



P. Huang et al, The Evolution of MAC Protocols in Wireless Sensor Networks: A Survey, IEEE Communications Surveys & Tutorials, vol. 15 (1), pp. 101-120, 2013

Myths

Wireless transmission issues

- The world is flat & radio transmission area is circular
  - signal strength is a simple function of distance
- All radios have equal range
- Link quality does not change
  - if I can hear you, you can hear me & if I can hear you at all, I can hear you perfectly
- The only source of packet loss is collision
- Broadcast is for free
- Energy is proportional to the number of packets and their size
- Duty cycling is the only way to reduce energy consumption

Propagation !

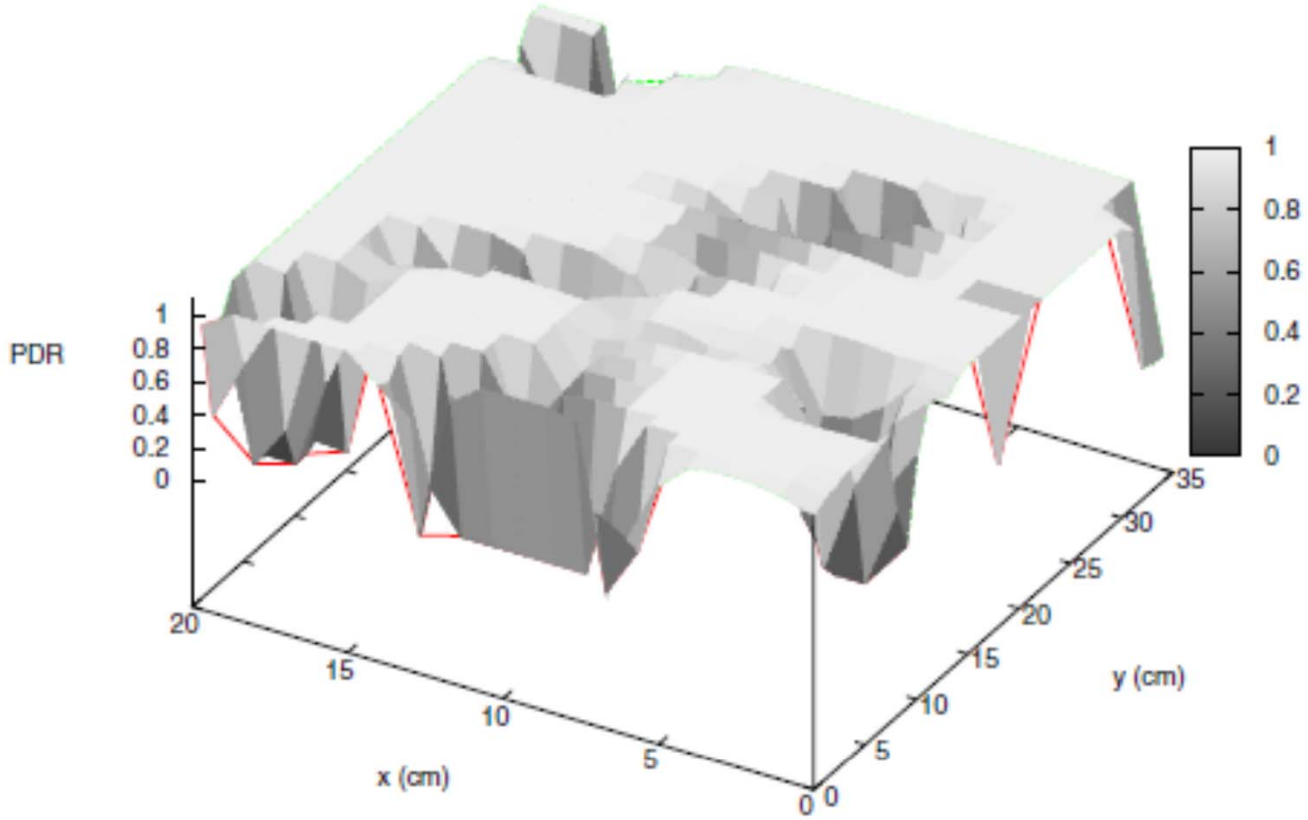
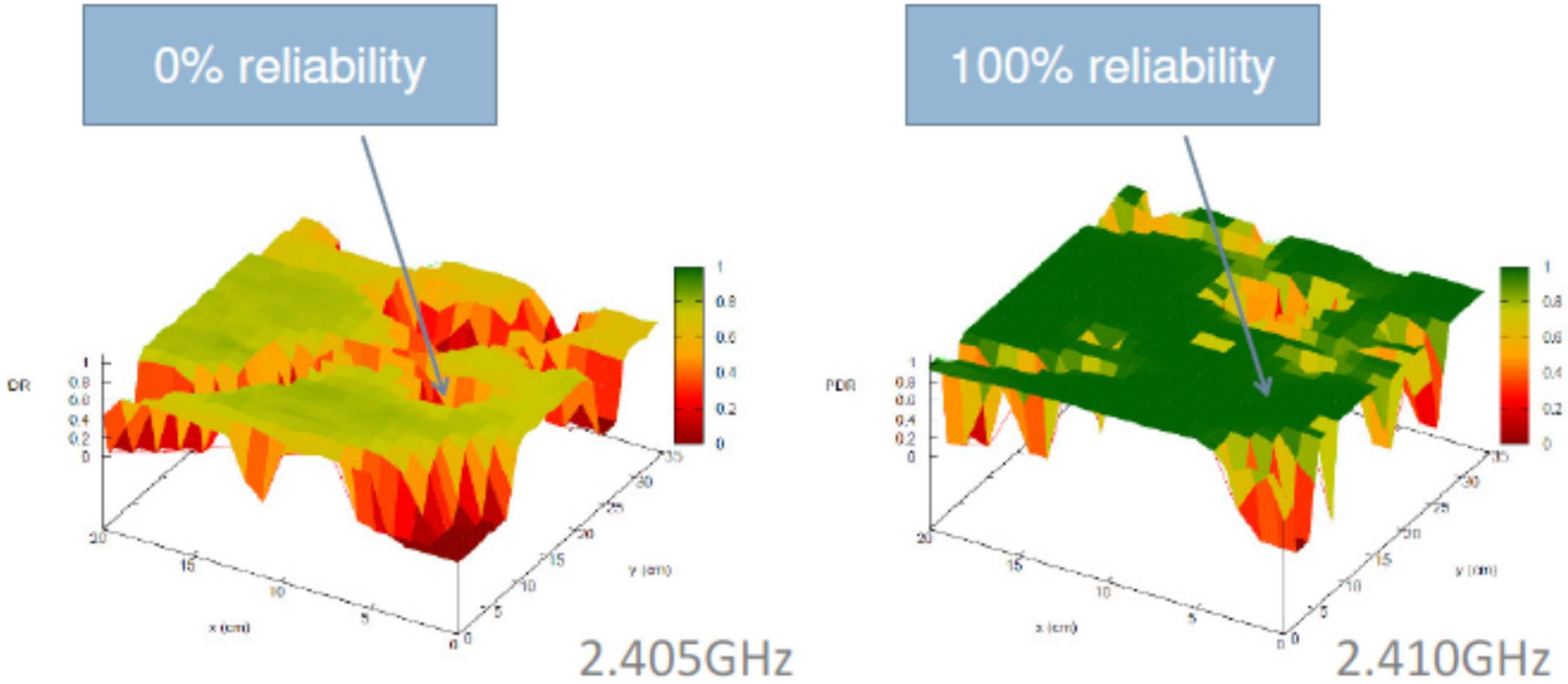


Fig. 1. Witnessing multipath fading. The x and y coordinates represent the position of the transmitter on a $20cm \times 34cm$ area; the receiver is static. The z axis (and the shade) represent the Packet Delivery Ratio, PDR. Results obtained for sender and receiver communicating on IEEE802.15.4 channel 20 (2.450GHz) while separated by 1m; transmission power is set to -16dBm.

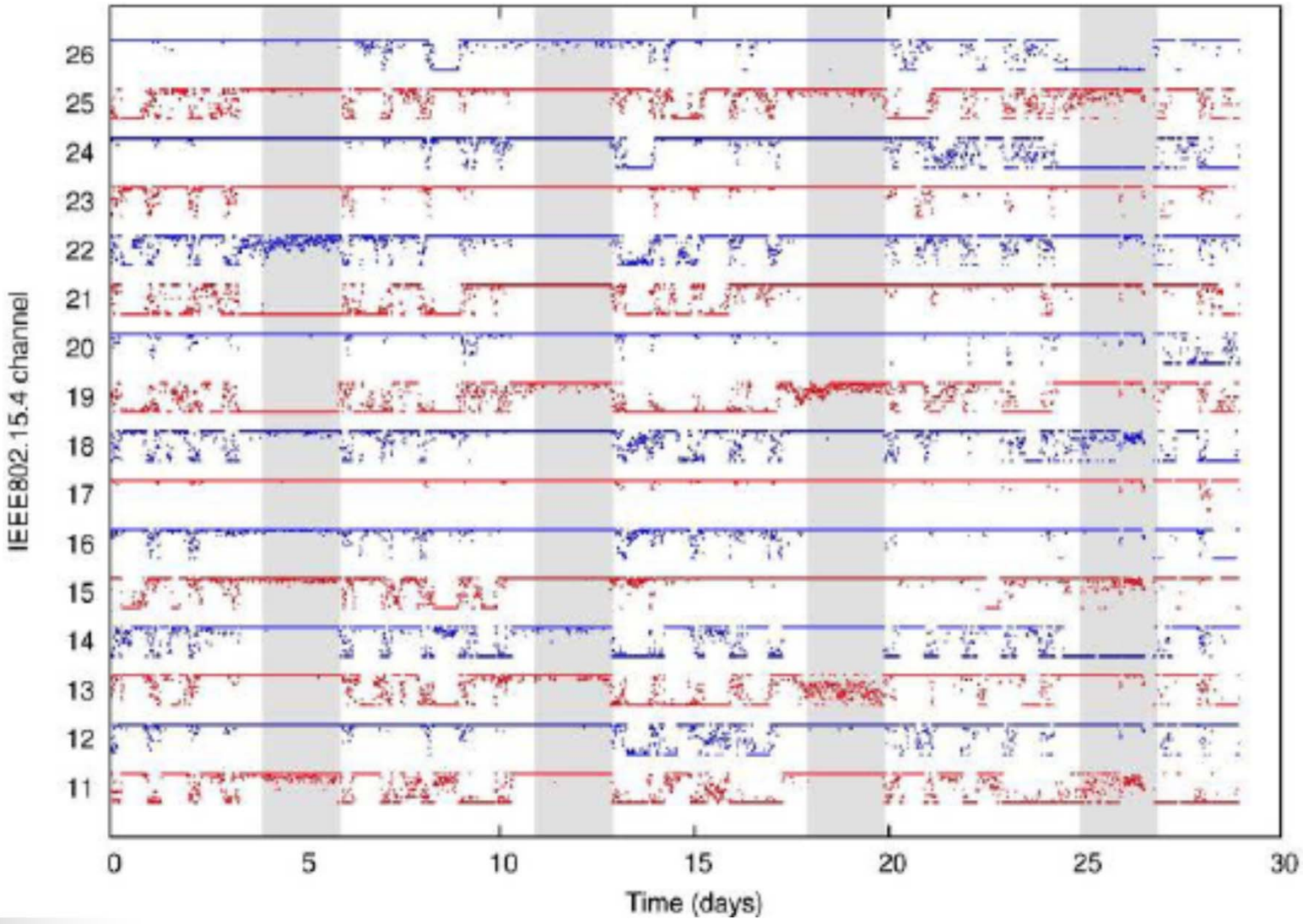
Source T. Watteyne, ICC 2010, p.1

Propagation !



Source T. Watteyne, DREAM
Seminar 2014

Propagation over time



Source T. Watteyne, DREAM Seminar 2014

Wireless Networks issues

- RT guarantees
  - Often fail in case of coexistence
  - CS and systematic channel hopping are good ways to support coexistence
    - CDMA should also be but requires power control
  - Routing should also be considered
- Energy consumption
  - Be aware that traffic is seldom constant
    - Fixed assignments are an overkill when traffic varies a lot
    - Future is likely to be in adaptive protocols or clever combinations of protocols (see S. Mo et al., Self-Adapting MAC Layer for Wireless Sensor Networks, RTSS 2013, pp.192-201)

Wireless Networks options

- TDMA
  - Good when traffic is constant (and also centralized)
  - Beware of coexistence (e.g. by having systematic hopping)
  - Beware of mobility
  - Is able to reach high channel utilization (with some care)
- Asynchronous (random) protocols
  - Good in terms of energy when traffic is low
  - Good for coexistence
    - Careful with coping with channel noise (M. Sha, et al., Energy-efficient low power listening for wireless sensor networks in noisy environments. IPSN '13, pp.277-288)

Choice

Criterion	Comments
Traffic model (deadline, period, inter arrival, ...)	Load evaluation for elimination or ranking.
Temporal guarantees	YES/NO ? Under which conditions ?
Reliability constraints	allows to reject solutions without retries
Maximum distance between nodes	allows to reject single hop solutions
Mobility or Immobility	allows to reject solutions based on long associations
Coexistence with other systems	allows to reject solutions that need planning
Dependence on Infrastructure or not	Allows to reject protocols that rely on this when this is not available
Single, Multiple sinks or Other patterns	Allows to reject protocols that do not support multiple sinks when this is needed by application
Energy constraints	If the constraint is on all nodes, this eliminates solutions with special coordination roles
Position referenced nodes	Allows reject protocols that need it when this is not available on the nodes
Simplicity	Ranking criterion

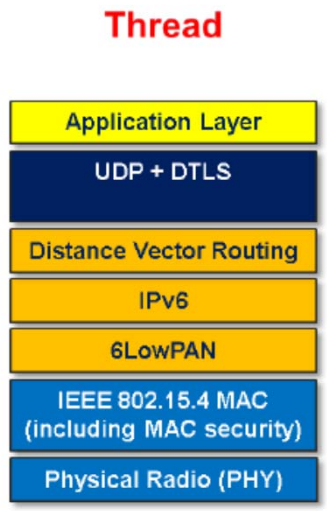
Other aspects

- Higher layers in particular application layer
  - May limit real-time (e.g. web services)
- Dependability (fault tolerance)
- Safety

- Tools
  - For deployment
  - For test
  - For management

Most serious contenders

- IETF (6LoWPAN, CoAP, ROLL/RPL)
  - MAC agnostic
  - Thread (Google) bears some similarities
- IEEE 802.15.4 (different options including with QoS
- ZigBee (uses 802.15.4)
- Bluetooth Low Energy (multihop since V4.2)
- Wireless Industrial (Wireless HART, ISA 100.11a)
- Home automation: Ant+, KnX, EnOcean, Z-Wave, WirelessMbus
- Long range low bandwidth (SigFox, LORA, Weightless)
- MQTT (-SN) is quite popular to connect to the cloud



RFC 1925 Fundamental Truths of Networking

- (3) With sufficient thrust, pigs fly just fine. However, this is not necessarily a good idea. It is hard to be sure where they are going to land, and it could be dangerous sitting under them as they fly overhead.

RFC 1925 Fundamental Truths of Networking (2)

- (7a) (corollary). Good, Fast, Cheap: Pick any two (you can't have all 3).

- (12) In protocol design, perfection has been reached not when there is nothing left to add, but when there is nothing left to take away.