Ultra Low Power Radio for Pervasive Computing

The last 10 meters

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Pervasive Computing or IoT

- “The **Internet of Things** refers to uniquely identifiable objects (Things) and their virtual representations in an Internet-like structure.“
- “Radio-frequency identification (RFID) is often seen as a prerequisite for the Internet of Things. If all objects of daily life were equipped with radio tags, they could be identified and inventoried by computers.”

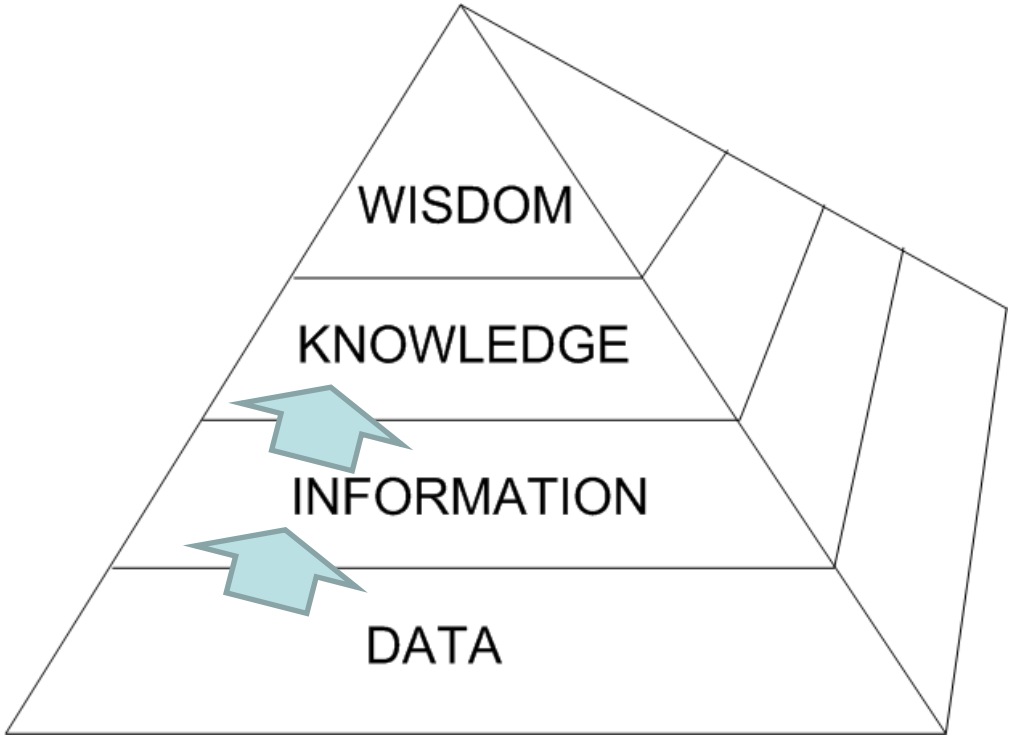
- This article **may contain unsourced predictions, speculative material or accounts of events that might not occur**.

IoT

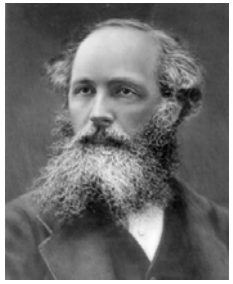
- The Internet of objects would encode 50 to 100 trillion objects, and be able to follow the movement of those objects.

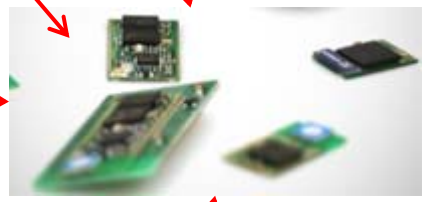
- Every human being is surrounded by 1000 to 5000 objects.

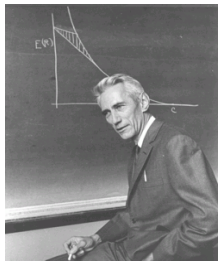
Sensors and RFID

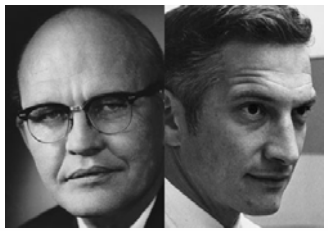


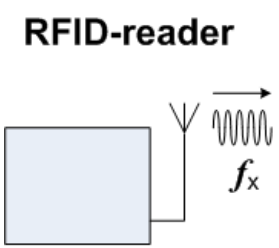
RFID

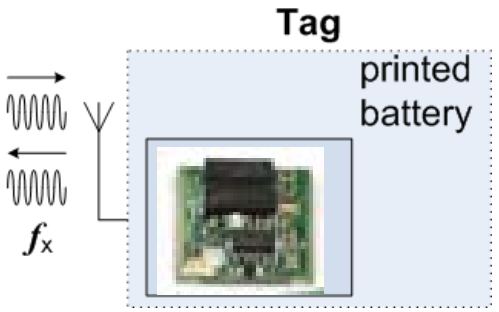




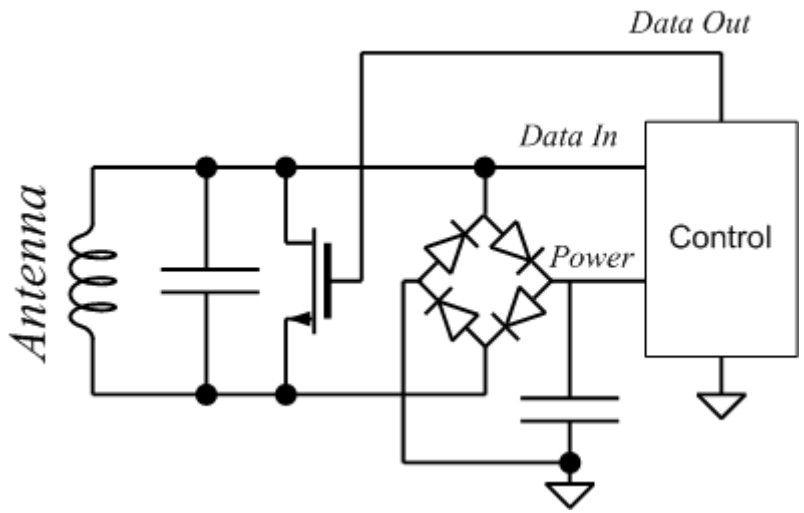




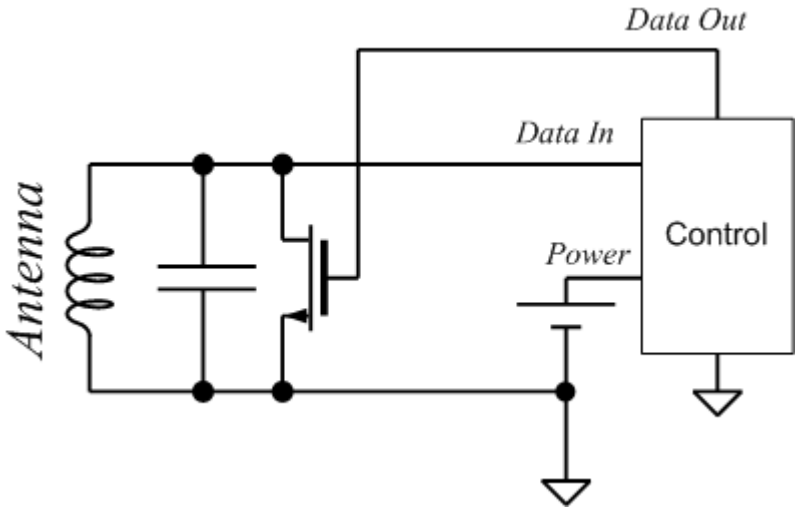




RFID



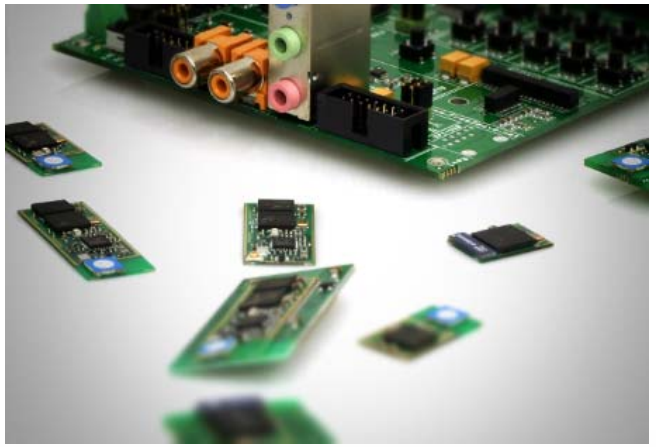
Passive



Active

Active or Passive RFID

- Active RFID opens up new application areas not reached by Passive RFID
  - Longer range
  - More functionality - sensors
  - Relaxed specification for the Active RFID reader



Active RFID

- Active RFID systems limited by **lifetime** of the tag (transponder)
- Lifetime is limited by **energy** consumption
- Save energy or increase energy available?

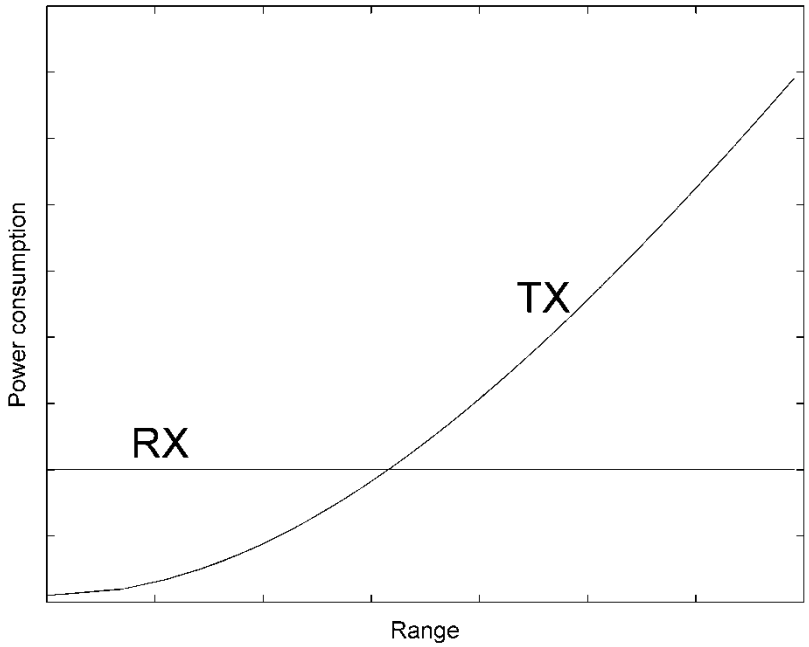
More energy

- Larger battery – Larger size and higher cost
- New battery technology – Higher cost and uncertain time to market
- Energy scavenging – Environment dependent and limited capacity

- Conclusion, saving energy is a preferable way forward
- Energy = Power x Time

Power

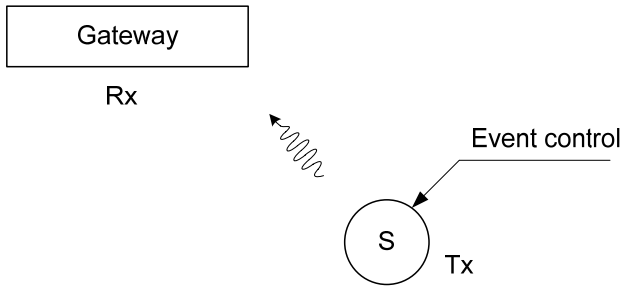
Power consumption vs. Range
RFID vs. “Traditional RF”



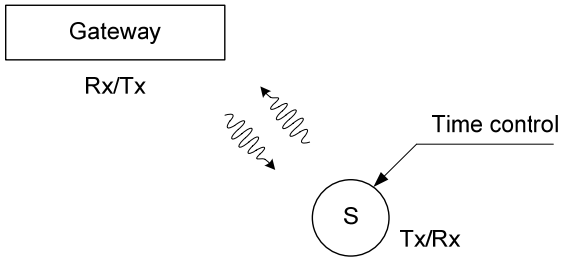
- $P_{RX} > P_{TX}$
- Protocol or Hardware
  - **Tag Transmit First** cause collisions on channel
  - **Duty cycling** increase response time and requires synchronisation between RX and TX
  - **Minimize** the cost of **power of receiving**

Application specific design

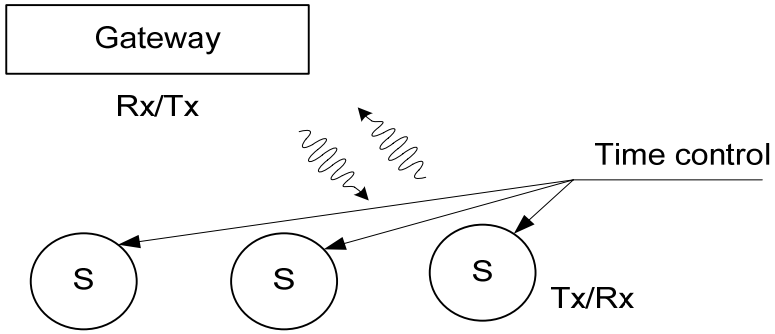
- Light switch

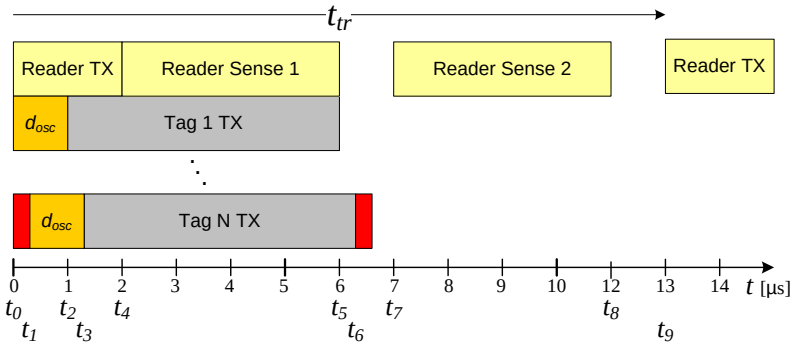


- Sensors/Inventory



Communication protocol

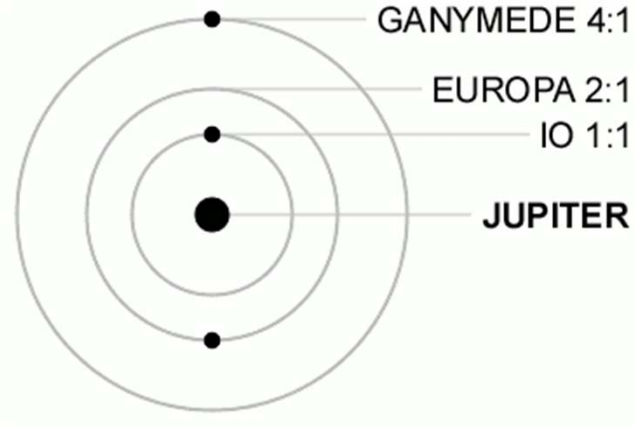


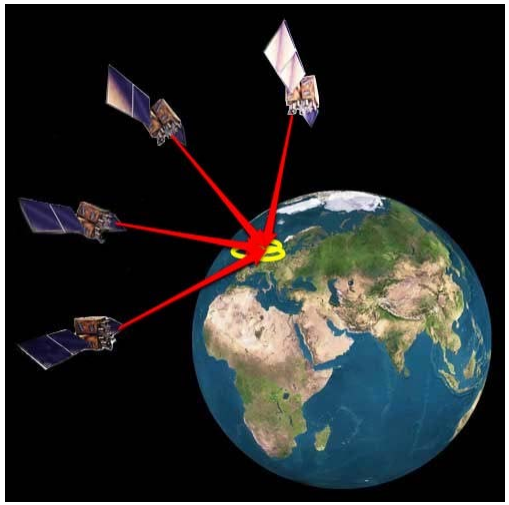


System performance depends on quality of a common time reference

Common reference of time

Old times, Moons of Jupiter or Earth





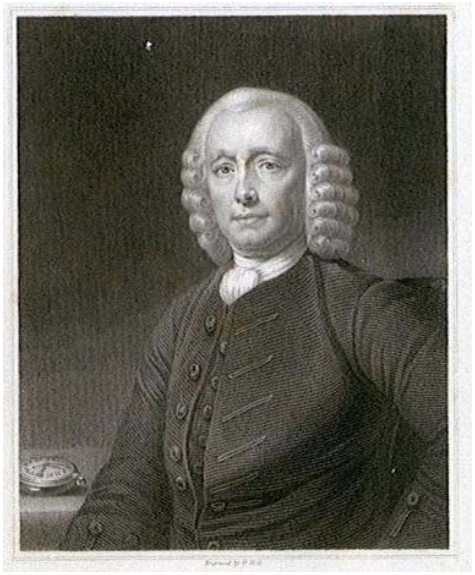
Today GPS

Accuracy and coverage

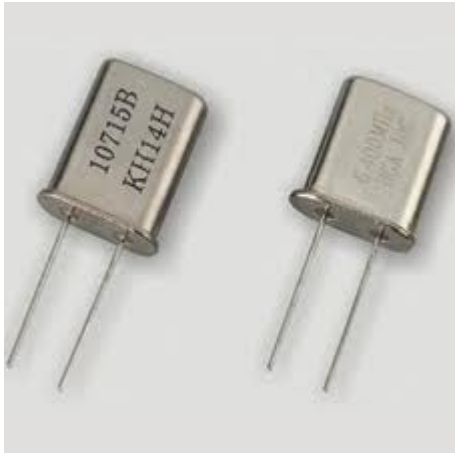
- On 22 October 1707 maritime disaster forced the British government to develop a better common reference of time

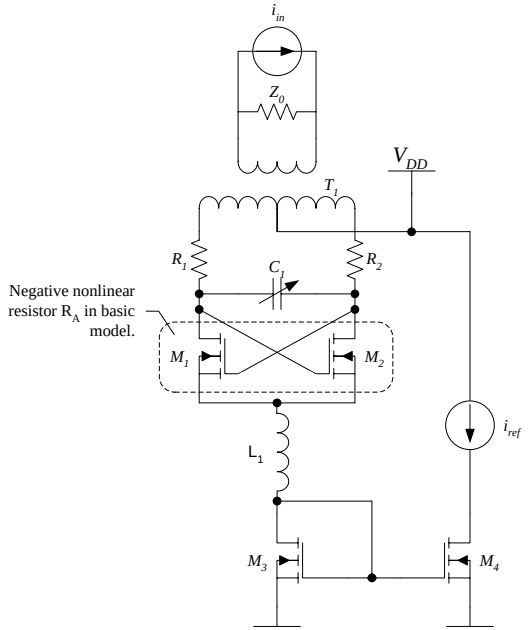
- The on board clock

On board clock



On board clock



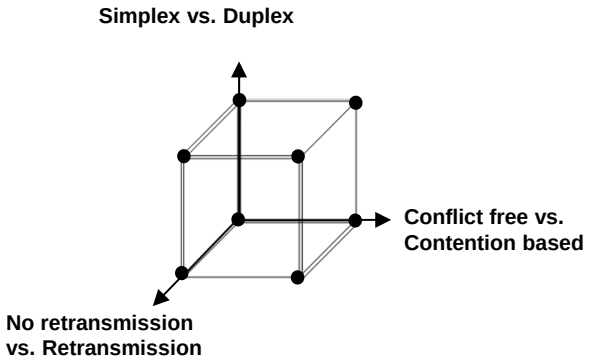


$$g_m = \frac{I_d}{\frac{nkT}{q}}$$

May be re-synchronized periodically, more robust solution.
Low cost components lead to inaccuracy or increased power consumption.

Minimize power

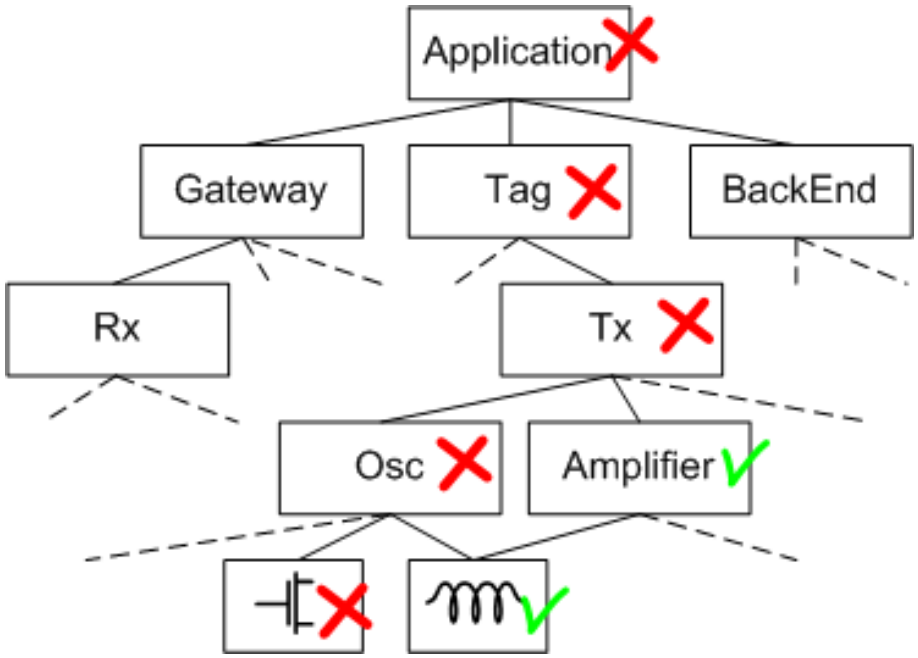
- Inaccurate frequency control
- Avoid retransmission
- Use simplex channel
- Short transmission burst



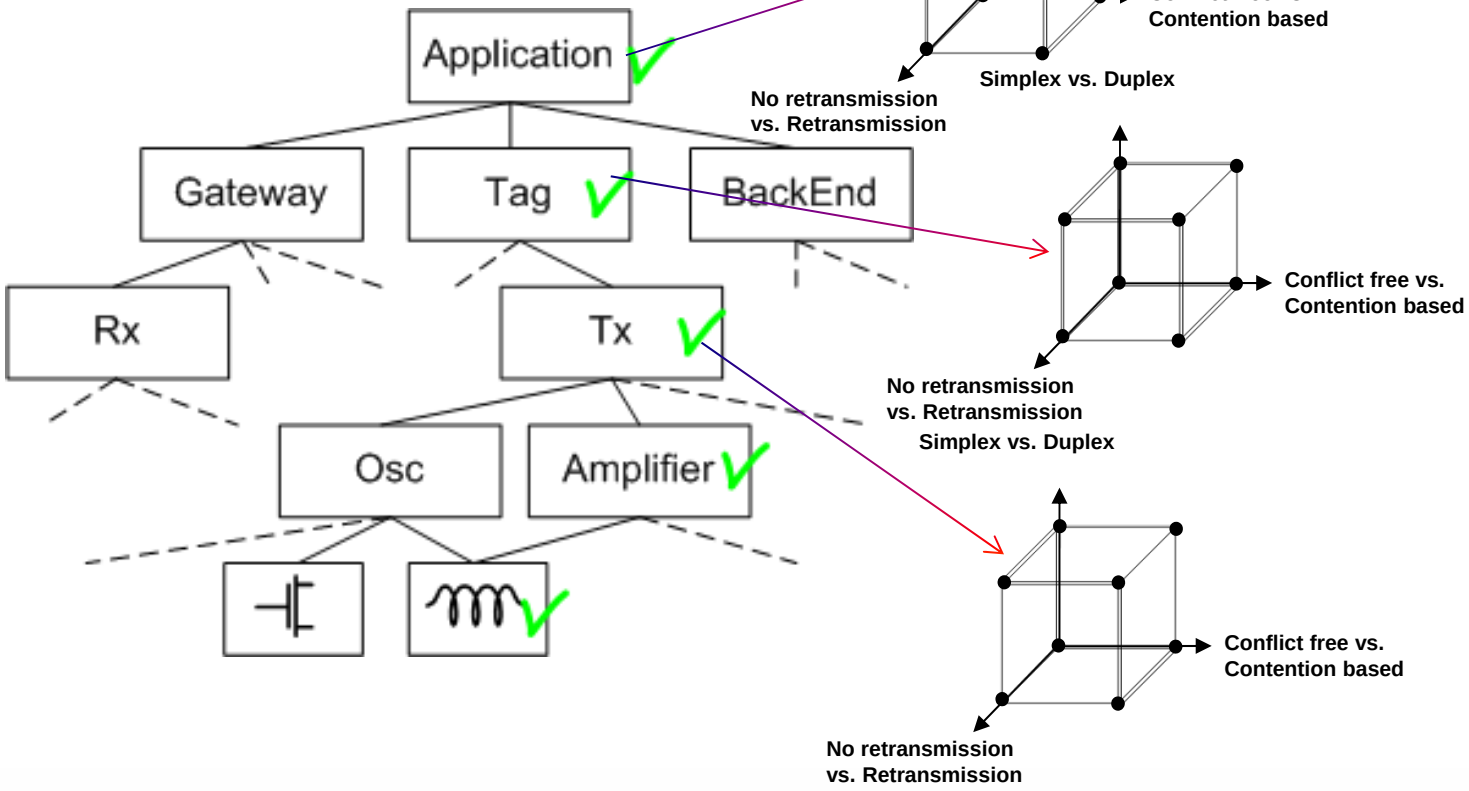
Short transmission burst

- Large bandwidth requires a high center frequency
- High center frequency gives LOS behavior – change protocol
- High center frequency gives loss in RF stages - change technology platform

Technology platform



Structured Design



Conclusion

- Co-design between Medium Access and Hardware is very important
- Do not solve a too large problem – domain specific design
- Last 10 meters covered with domain specific designs
- Large scaling is not easy with heterogeneous solutions – structured design