Center for Information Technology Research in the Interest of Society

Roadmap to Ubiquitous Connectivity

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UC Berkeley/National Semiconductor

CITRIS in Europe June 20, 2006

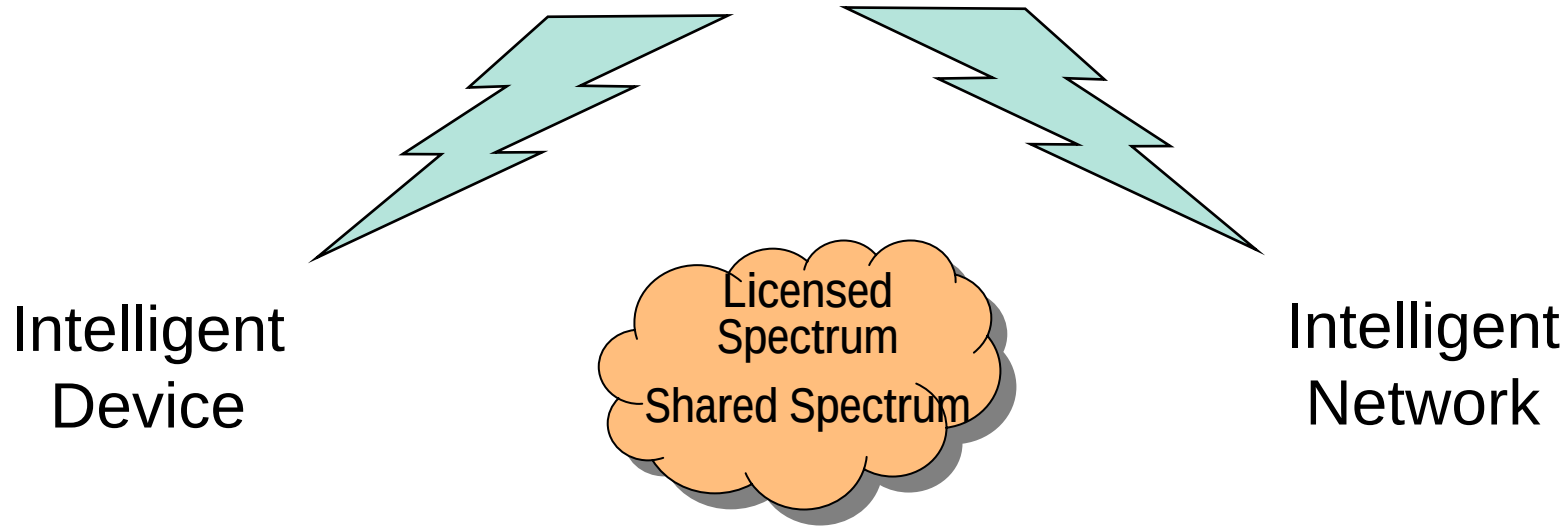
Wireless Connectivity: Reflection or extra dimension of our personality?

- Personal and Social life
- Health
- Security
- Business
- Bridging the Digital Gap

Intelligent Wireless System

Awareness

Ambient | Location | Energy | State of Mind | Efficiency



Pervasive Silicon Connectivity!

Smaller Transistor

Number of Transistors/inch doubles every 18 months

More Efficient Spectrum Usage

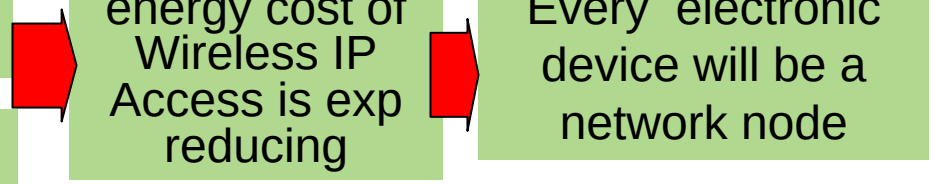
Spectrum Efficiency of Comm systems Doubles every 30 months

More energy efficient bits

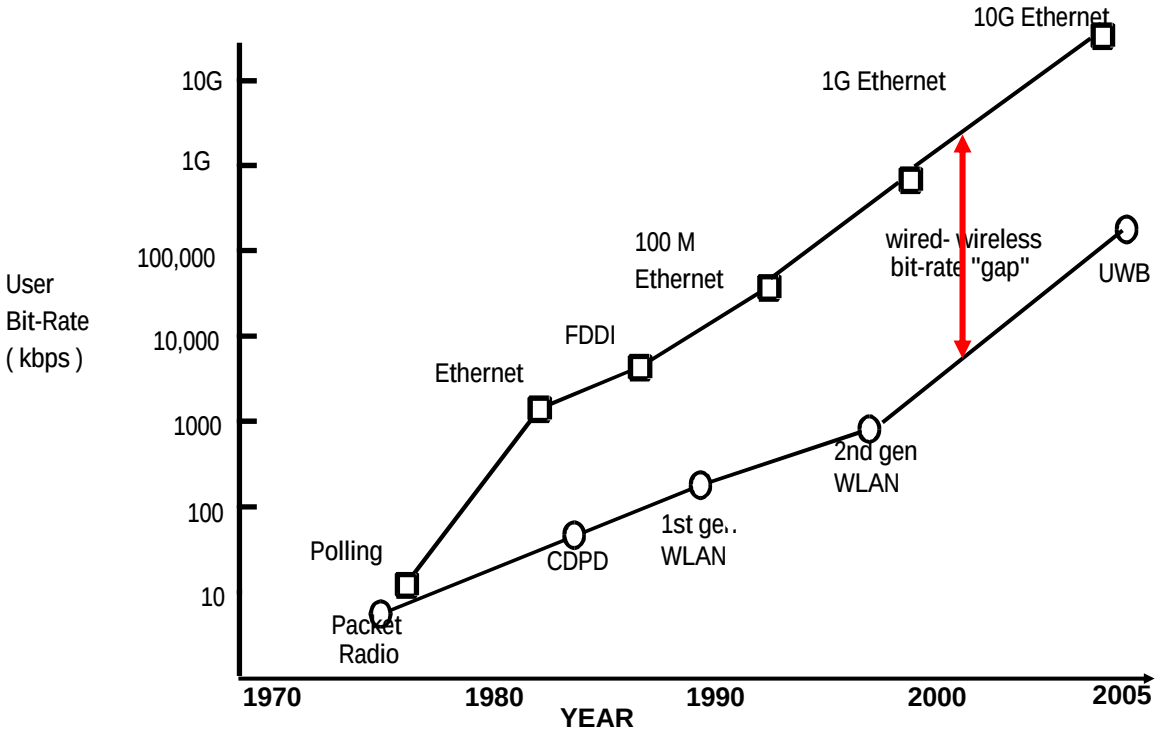
Energy/bit/s/m reduces exponentially

Smarter bits

Information/bit increasing



Wireless Complementary to Wired



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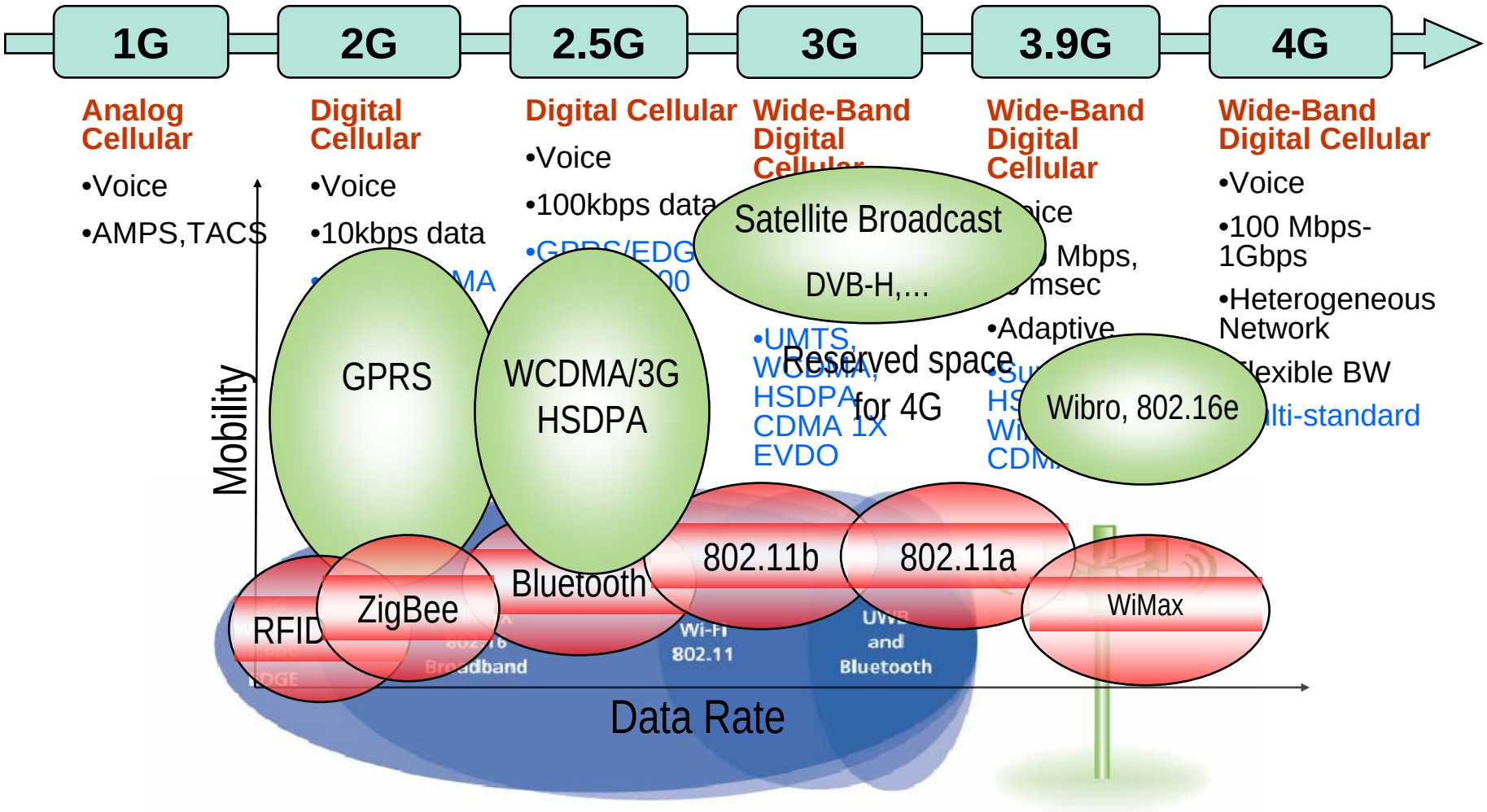
Wireless Drive



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Wireless Network Lab's Research

Focus

Wireless Communication System Design:

- Mixed signal Processing
- Multiple Access Techniques
- QoS

Projects

- Ultra Low Power Wireless Sensors
- DSRC
- Cognitive Radio

Energy Crisis

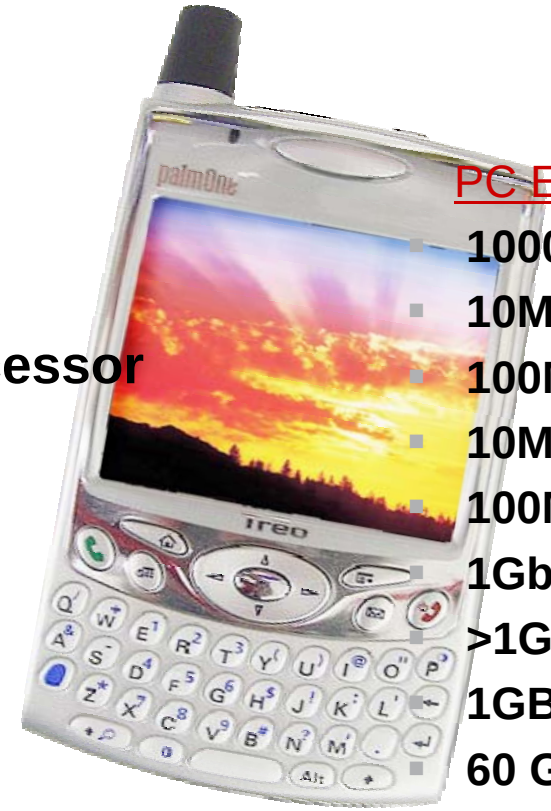
- Macro Level

Nirvana

Energy Crisis- Micro level

Power drains:

1. **DISPLAY**
2. **Media processor**
3. **Modem**
4. **Others**

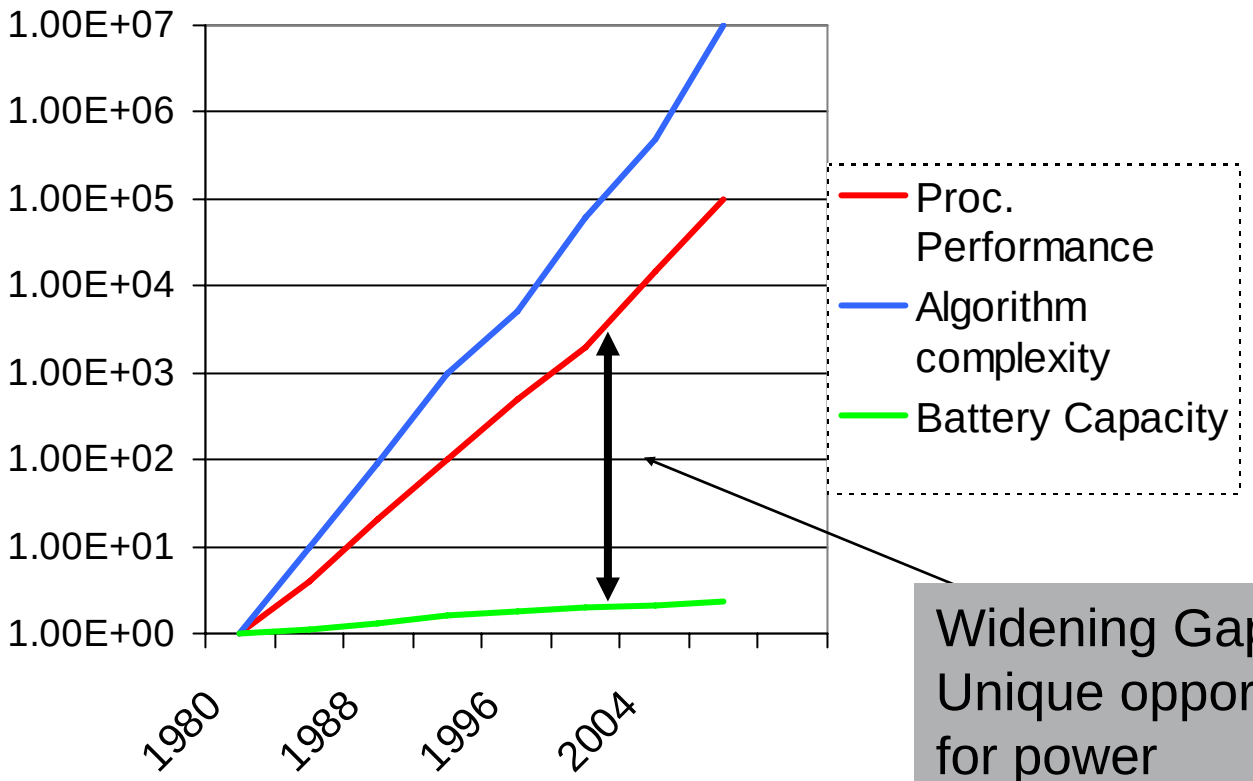


PC Equivalent Performance

- **1000 DMIPS CPU**
- **10M polygon/sec 3D graphics**
- **100M pixel/sec MPEG4 codec**
- **10Mbps 3G/4G WWAN**
- **100Mbps 802.11 WLAN**
- **1Gbps UWB WPAN**
- **>1GB DRAM**
- **1GB FLASH**
- **60 GB Hard Disk**

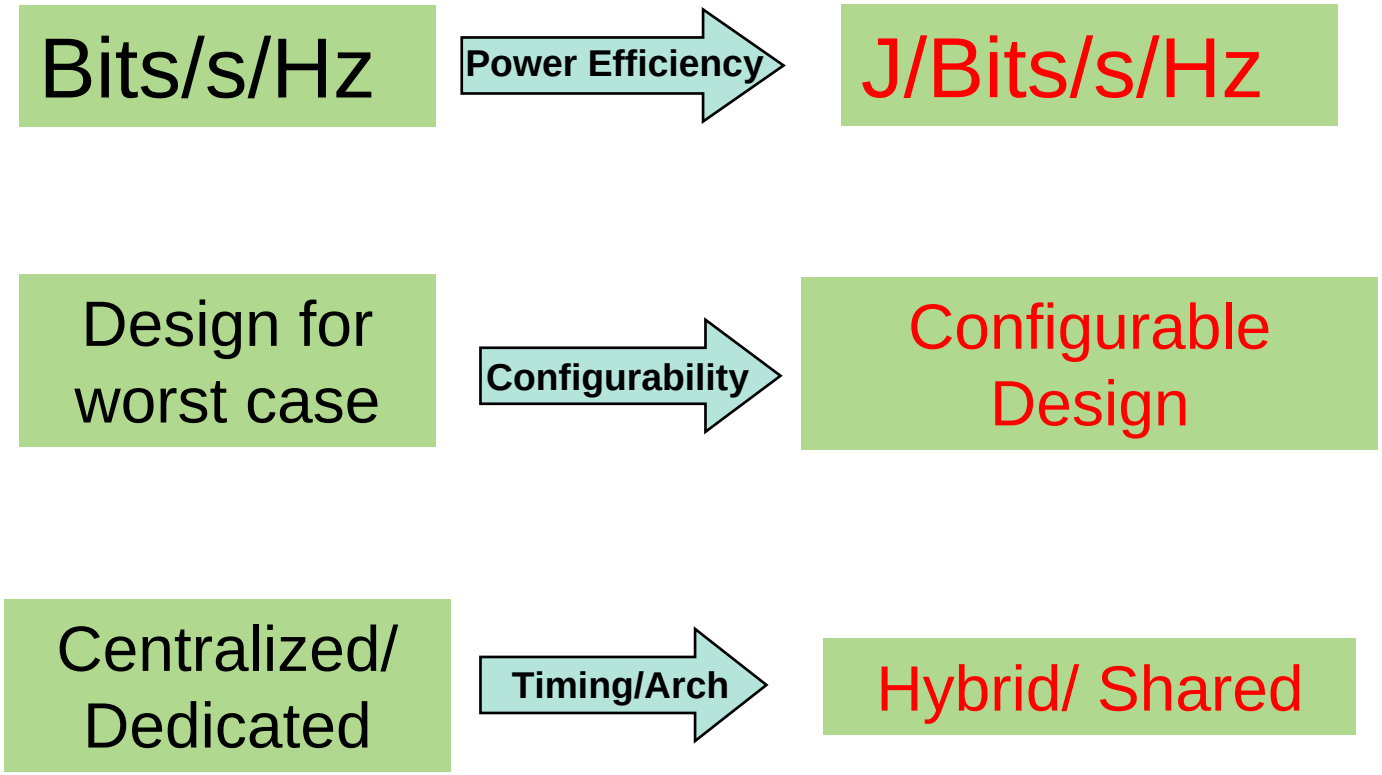
Ambient Aware system with Intelligent Power Management

Energy Efficiency:
Necessity not Luxury

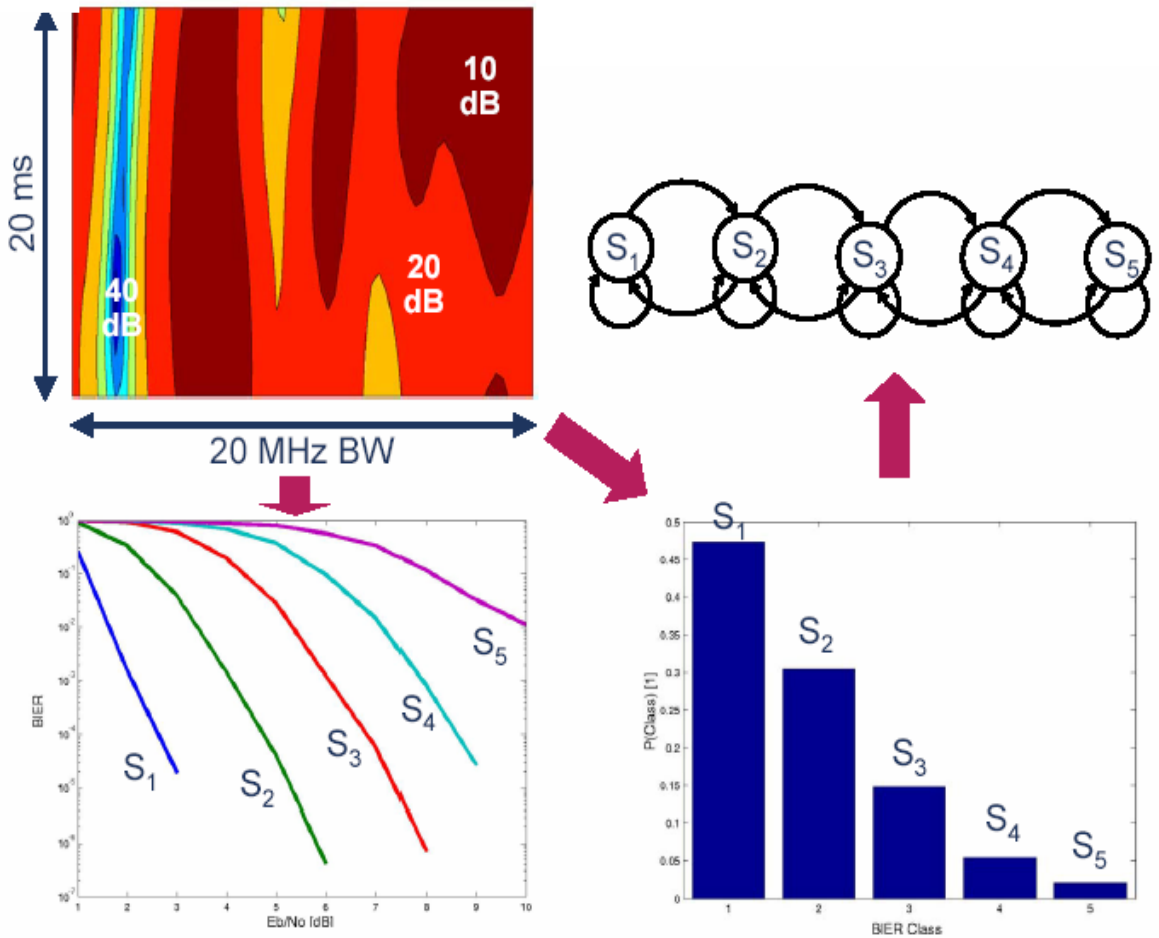


Widening Gap: Unique opportunity for power management

New Design Paradigm



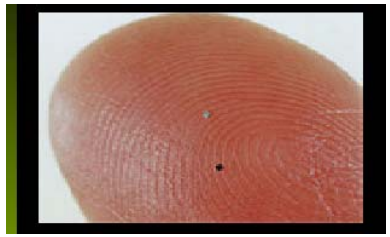
Channel Effect



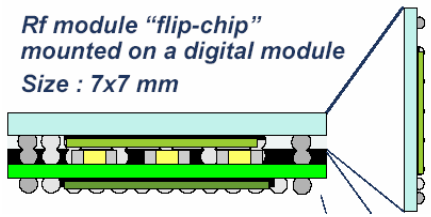
IMEC Collaboration

Ultra Low Power Wireless Sensors

- **Ultra-low power mixed signal design**
  - **Less than 10pJ/conversion**
- **Sub-threshold signal processor**
  - **20uw @ 100Khz**
- **Intelligent communication design**
  - **Intelligent MAC, Standby power optimization**
- **MEMS based wireless “ Feeling Sensor”**
  - **Polymer based biosensors**

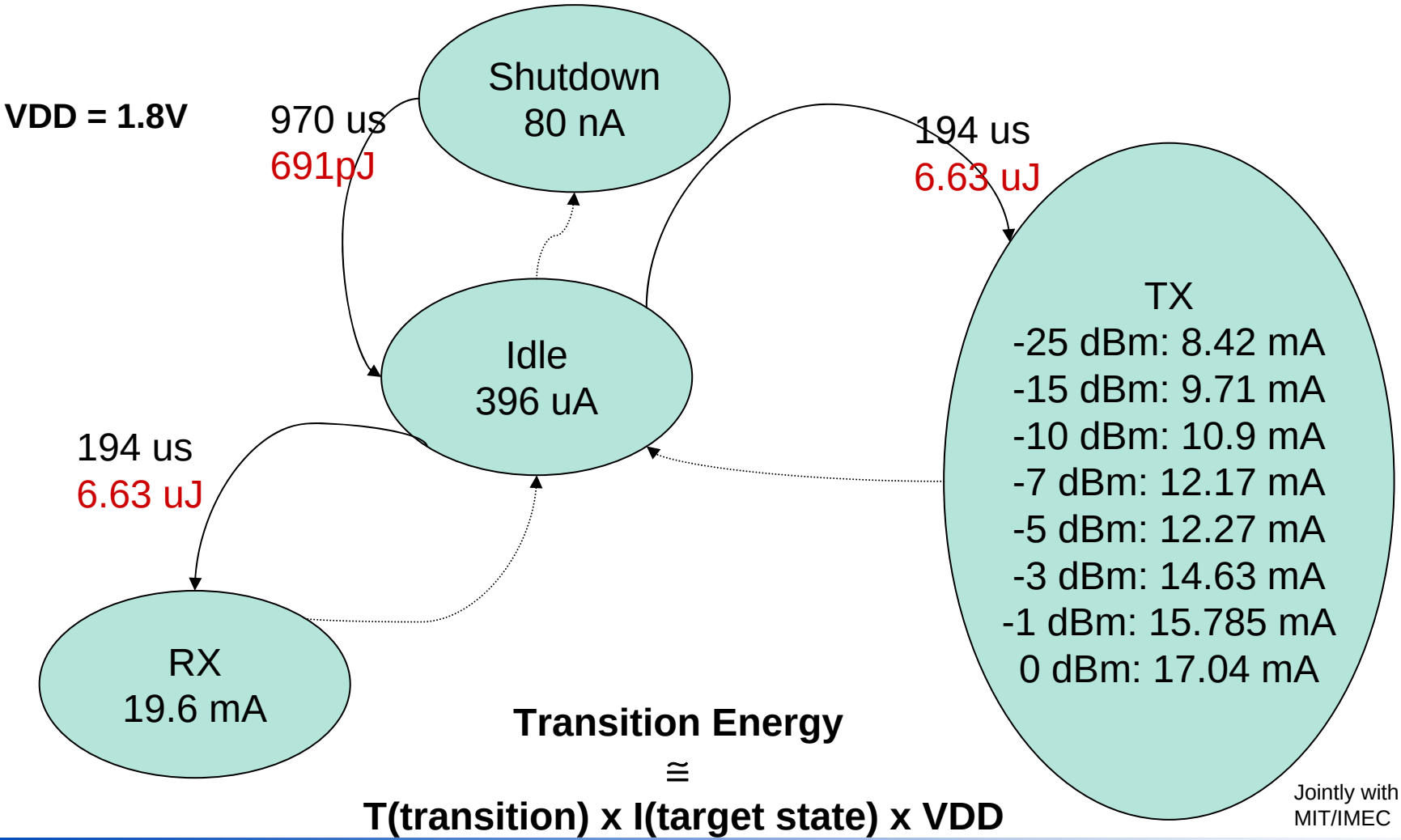


Plastic ISFET



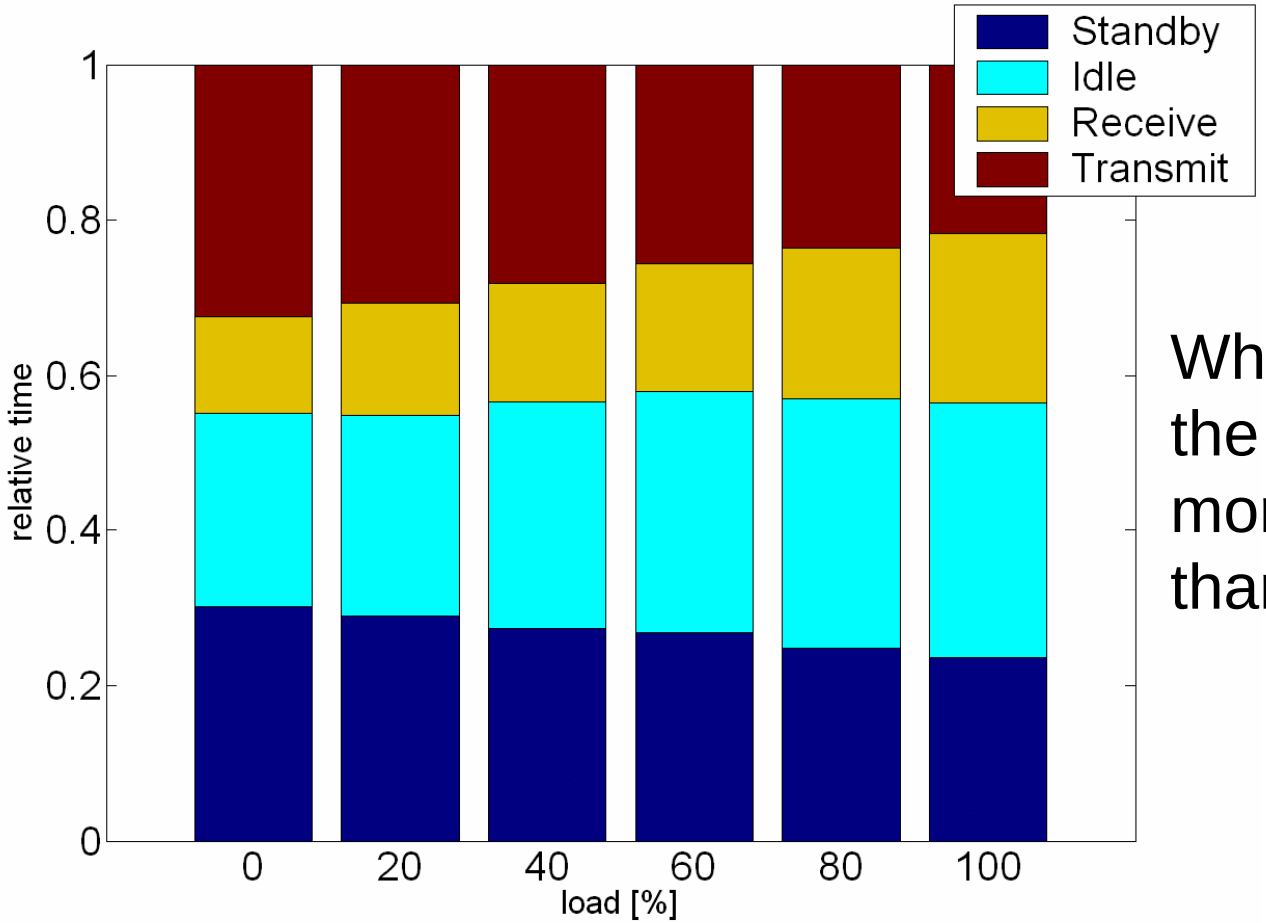
Jointly with IMEC

Energy Analysis



Where does the power go?

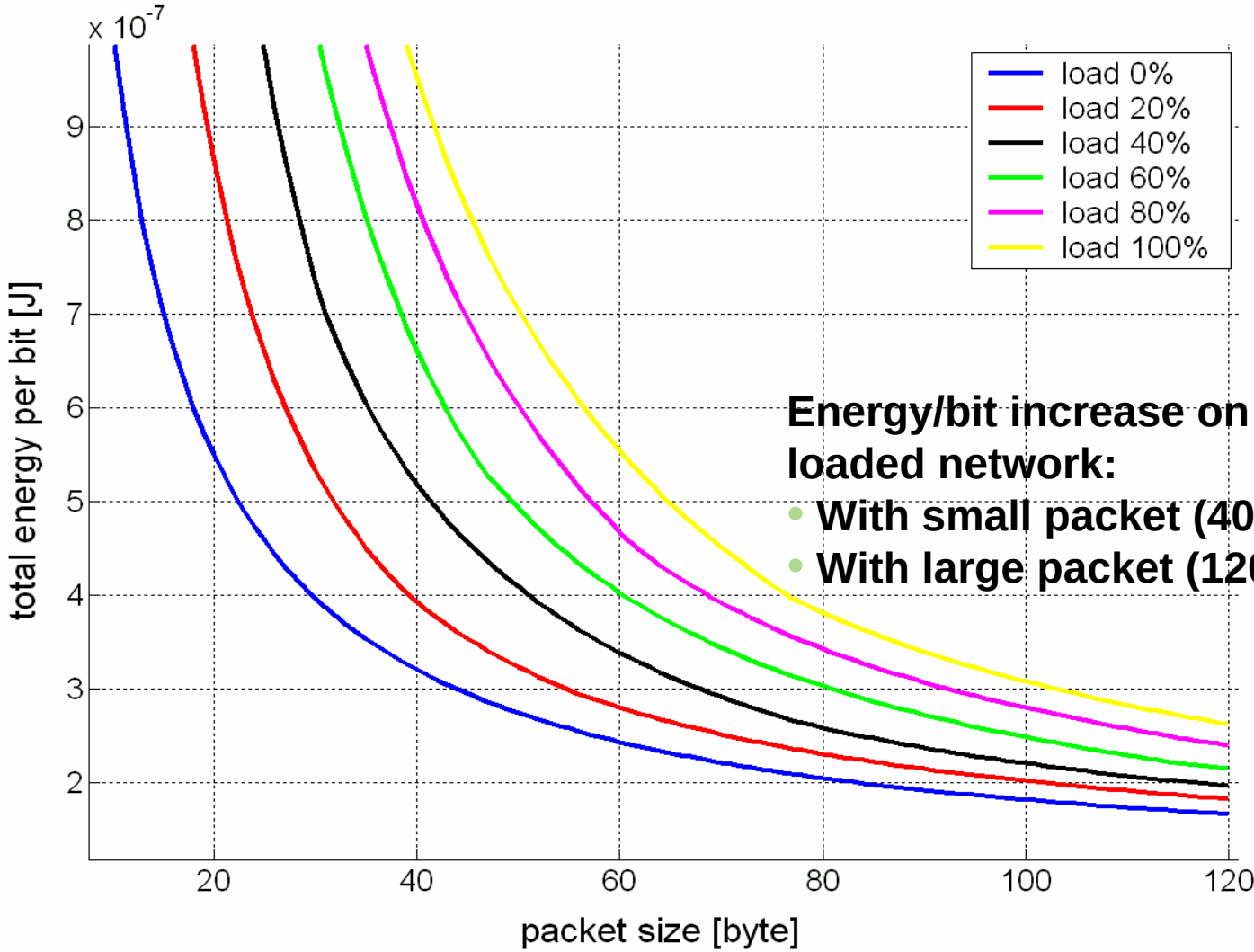
Breakdown between the states



When load is high, the node spends more time in RX than in TX mode!

Jointly with MIT/IMEC

Network load

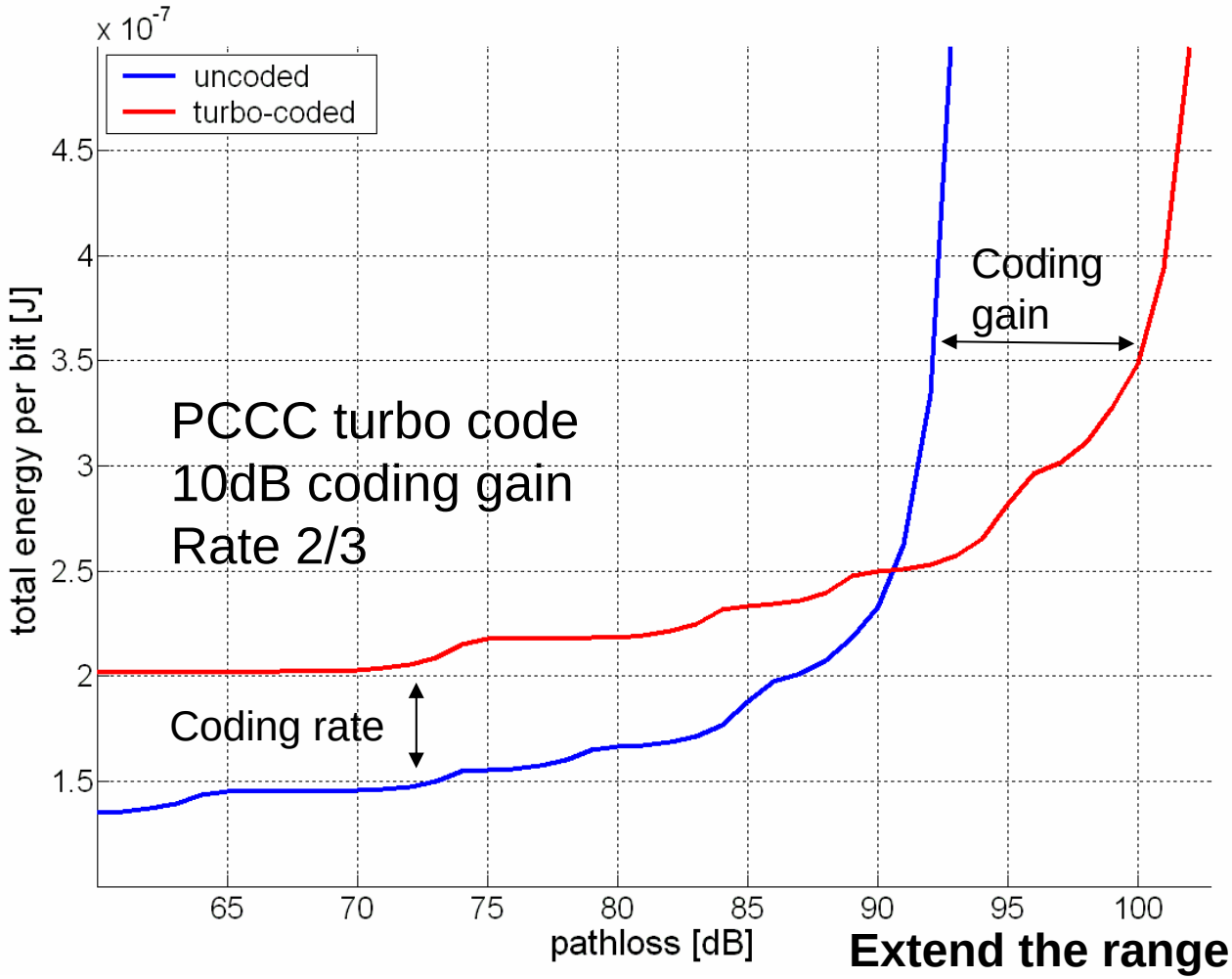


Energy/bit increase on highly loaded network:

- **With small packet (40 bytes) : 3x**
- **With large packet (120 bytes): 1.5x**

Jointly with MIT/IMEC

Coding Gain



Extend the range: YES
Improve energy: NO

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Comprehensive Energy model

Energy efficiency metric:

$$\eta = \frac{E[Energy_{total}]}{E[Payload]}$$

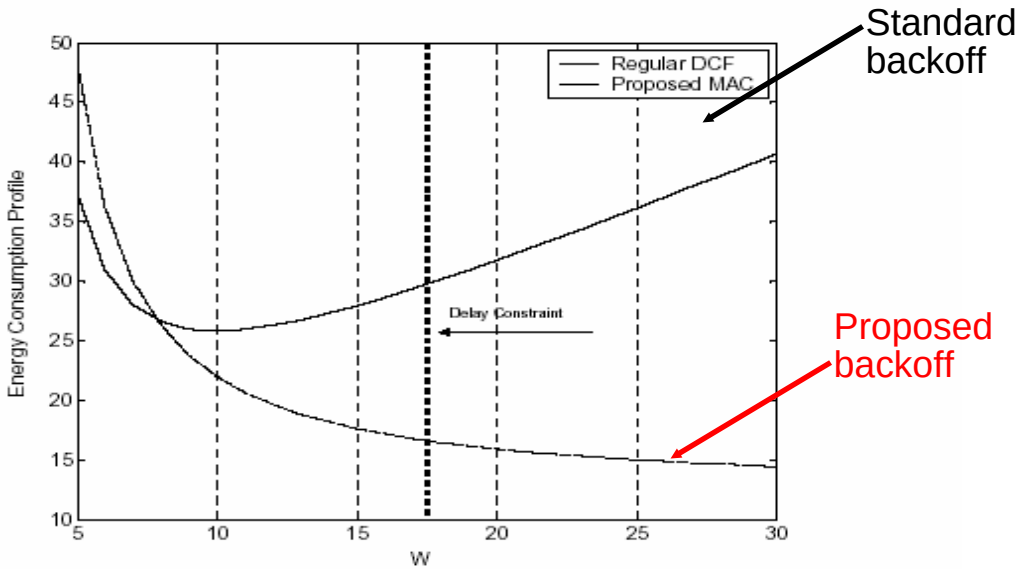
$$E[Energy_{total}] = \sum_{k} [Energy_{t0tal} \mid state_k] P[state_k]$$

TX, RX, Collision, sensing, Transitions, ramp up

New model for total energy was used to optimize back off strategy in an ad-hoc network.

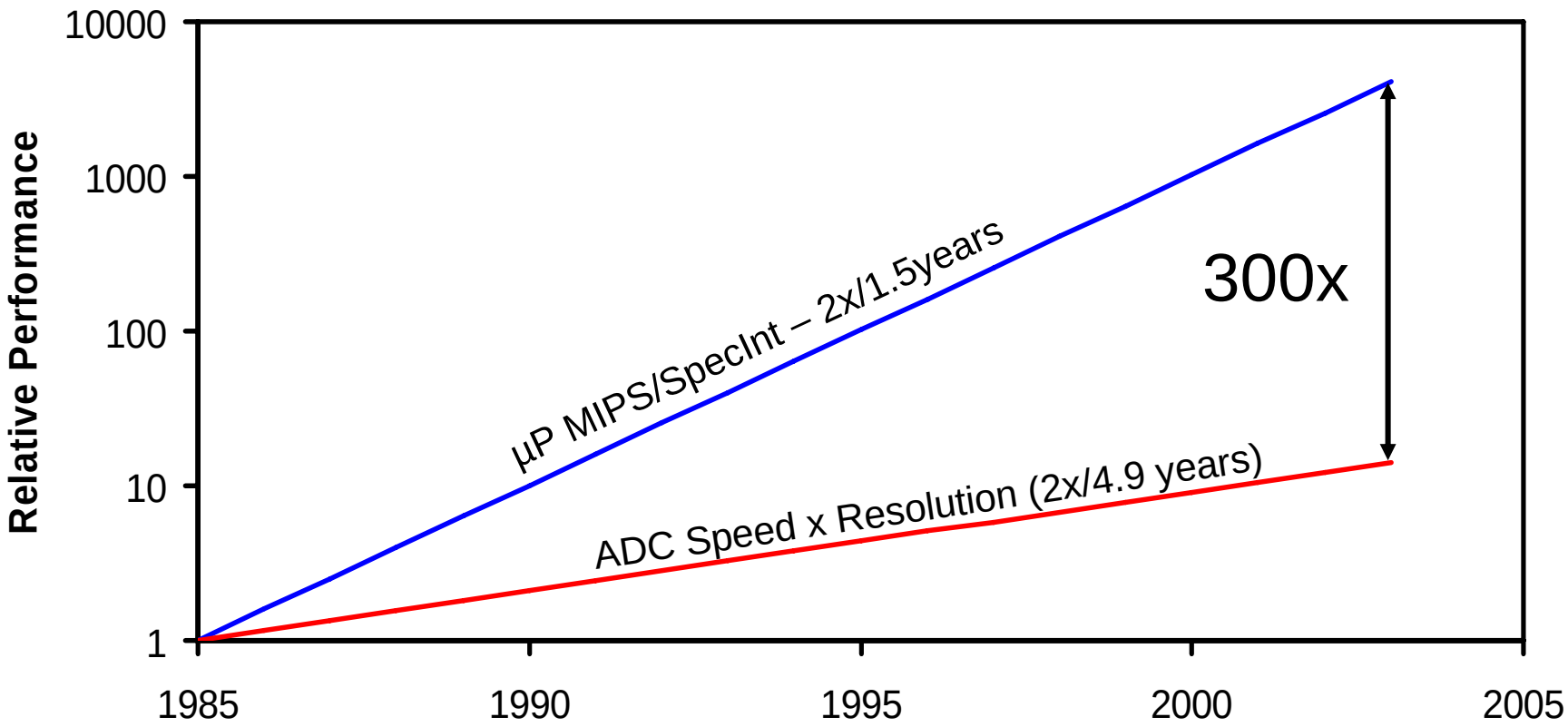
Energy Efficient MAC

$$\eta = \frac{r + W - 1}{(1 - \frac{1}{W})^{N-1}} - \frac{(L-1)\cdot(W-1)}{L}$$



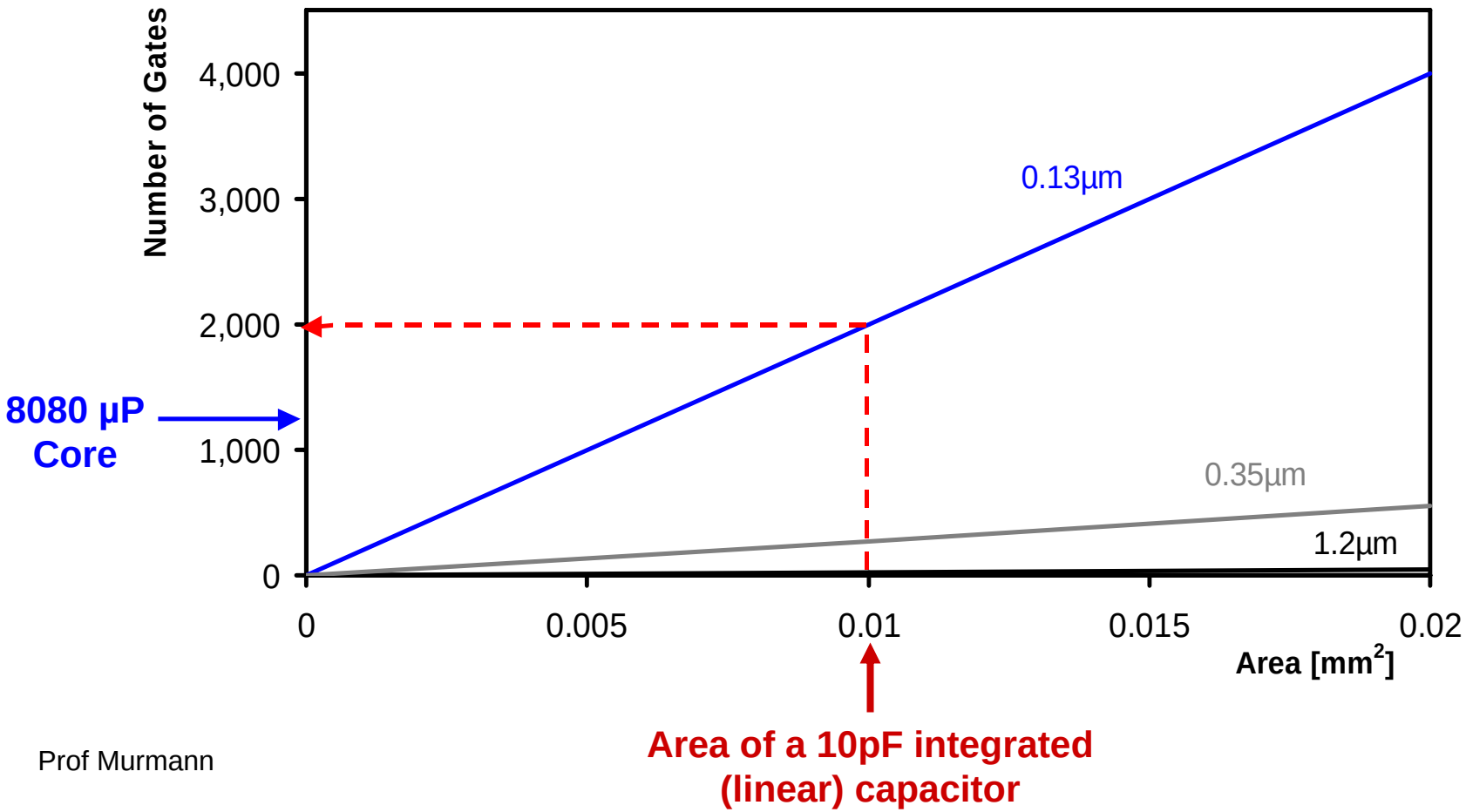
Resetting back-off is more energy efficient than DCF backoff due to carrier sensing overhead.

Mixed Signal Processing: Performance Divergence - µP vs. ADC



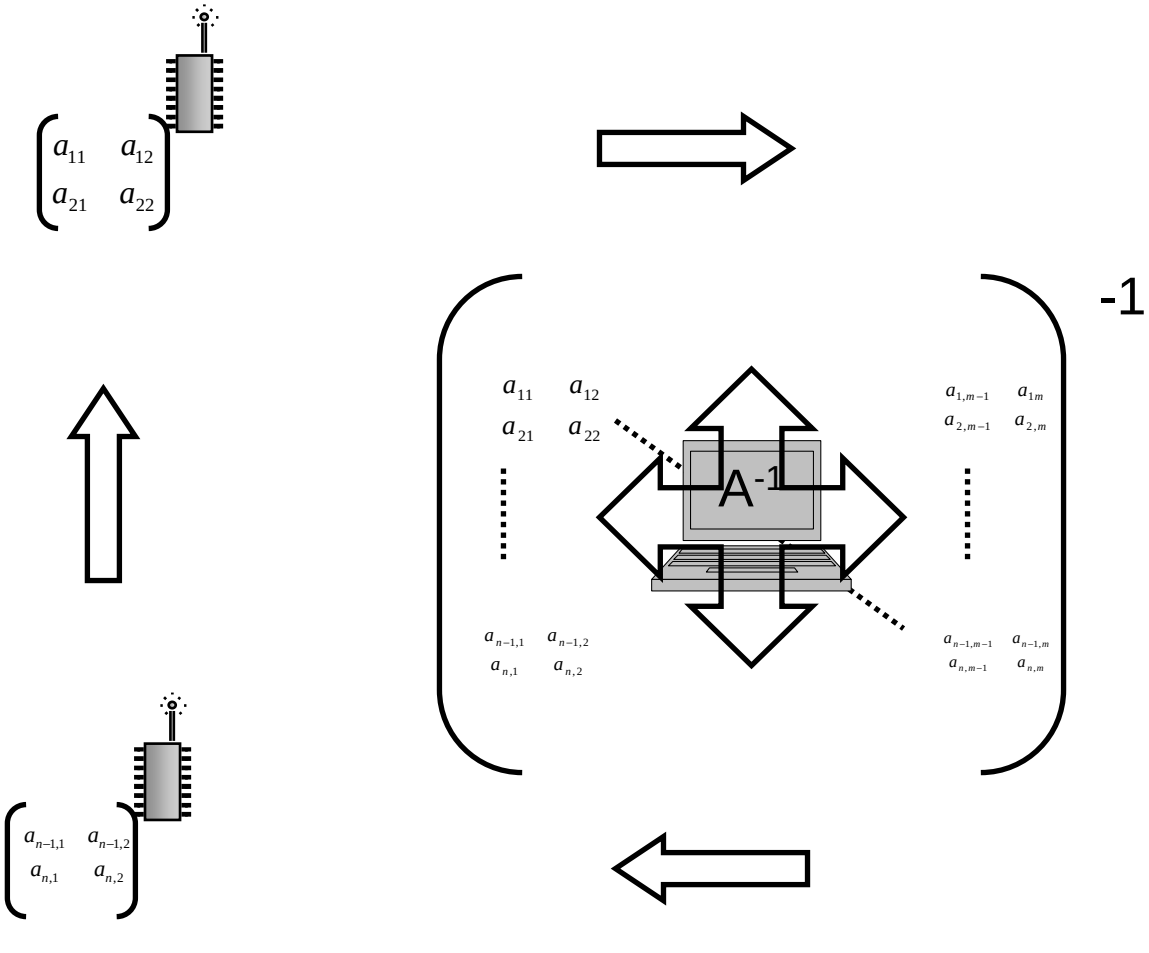
Prof Murmann

Digital + Analog Processing

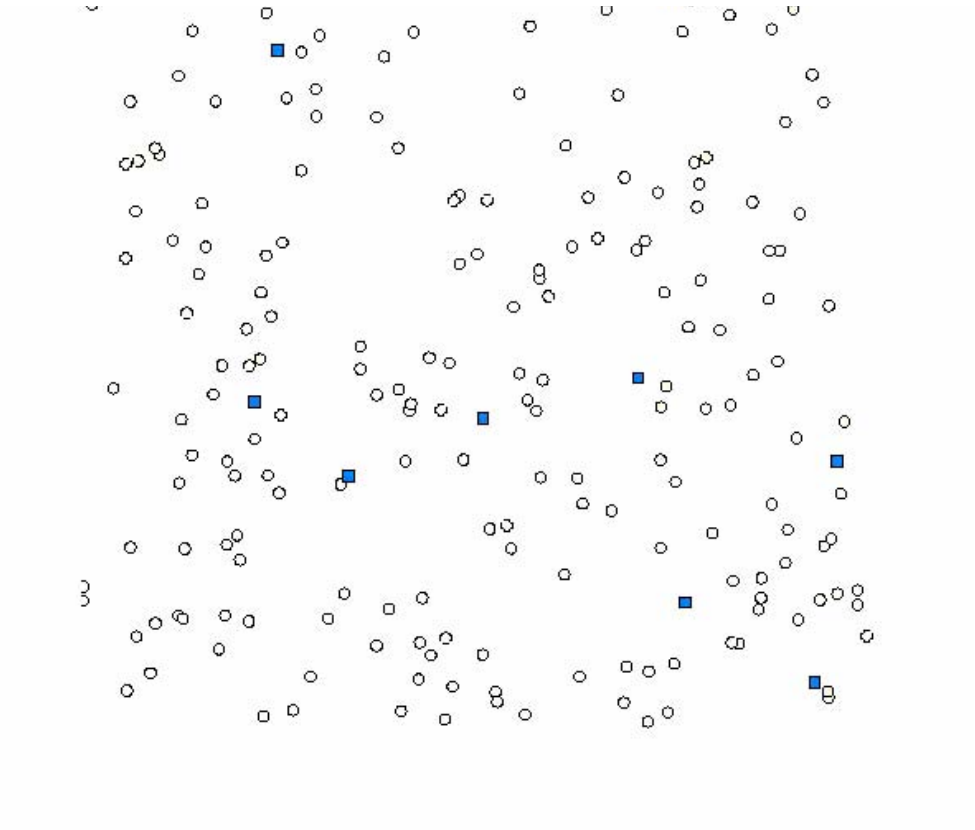


Prof Murmann

Distributed Wireless processing

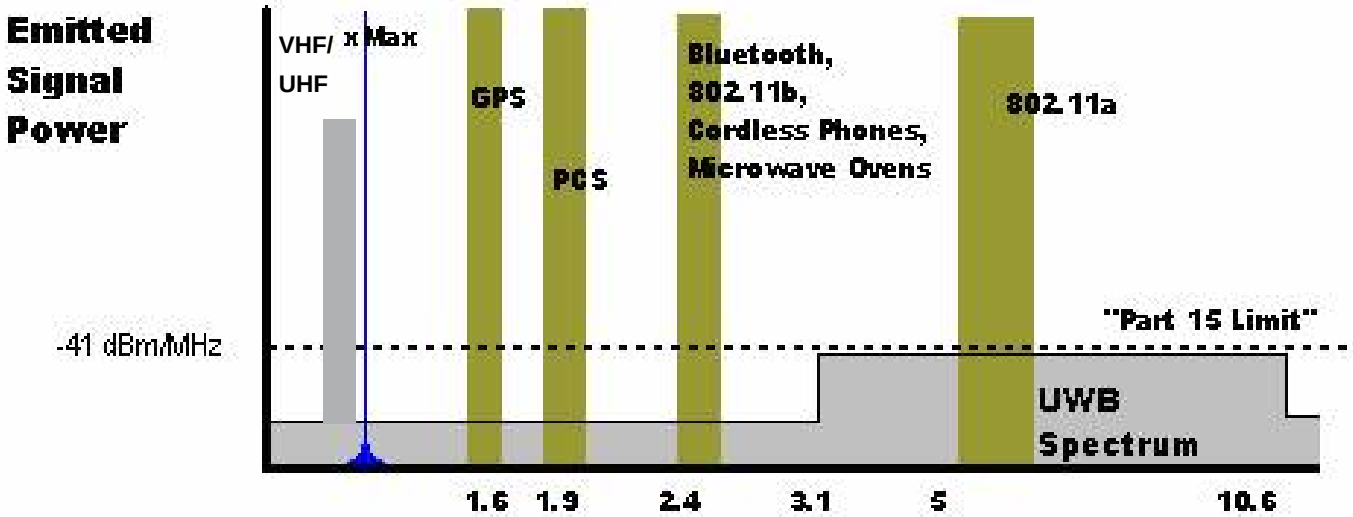


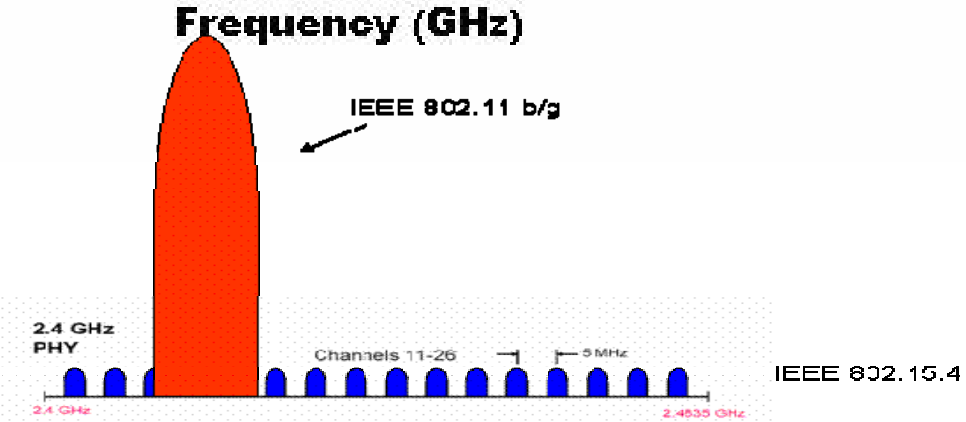
Sensor Networks collaborative Processing



Jointly with Stanford

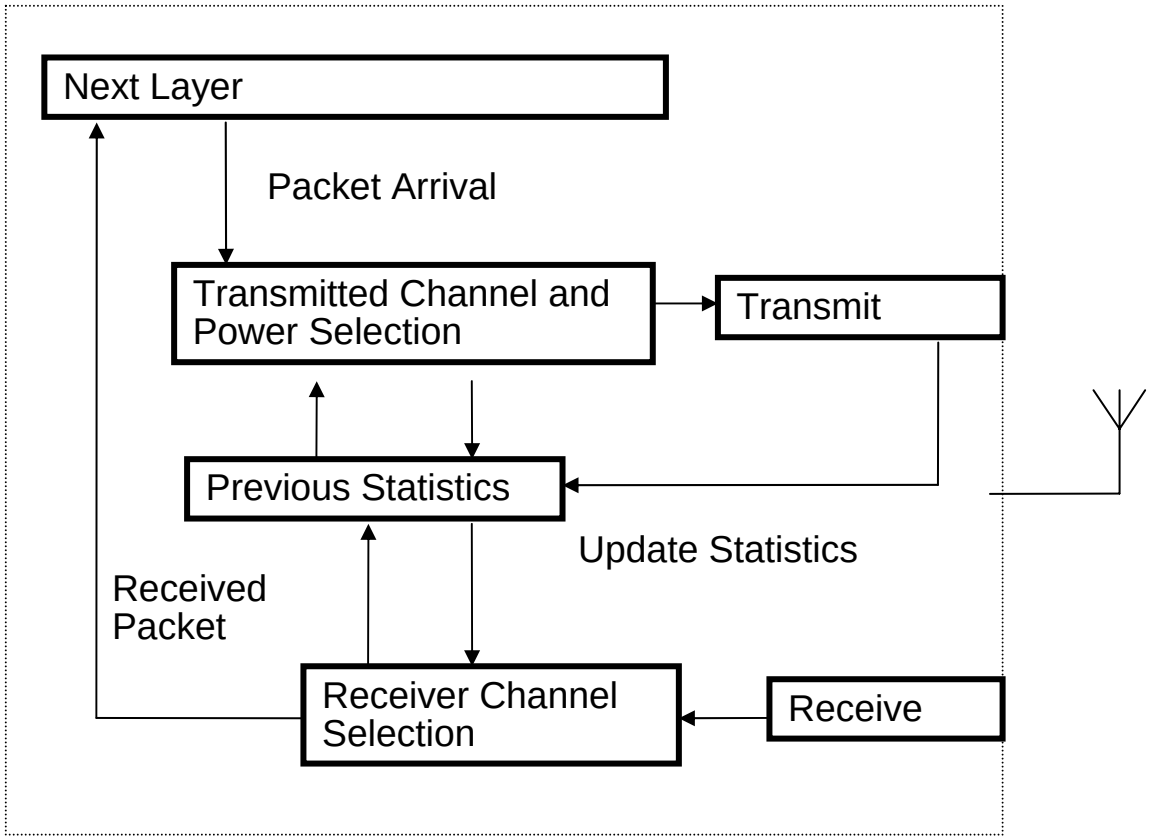
Spectrum sharing- Cognitive Radio



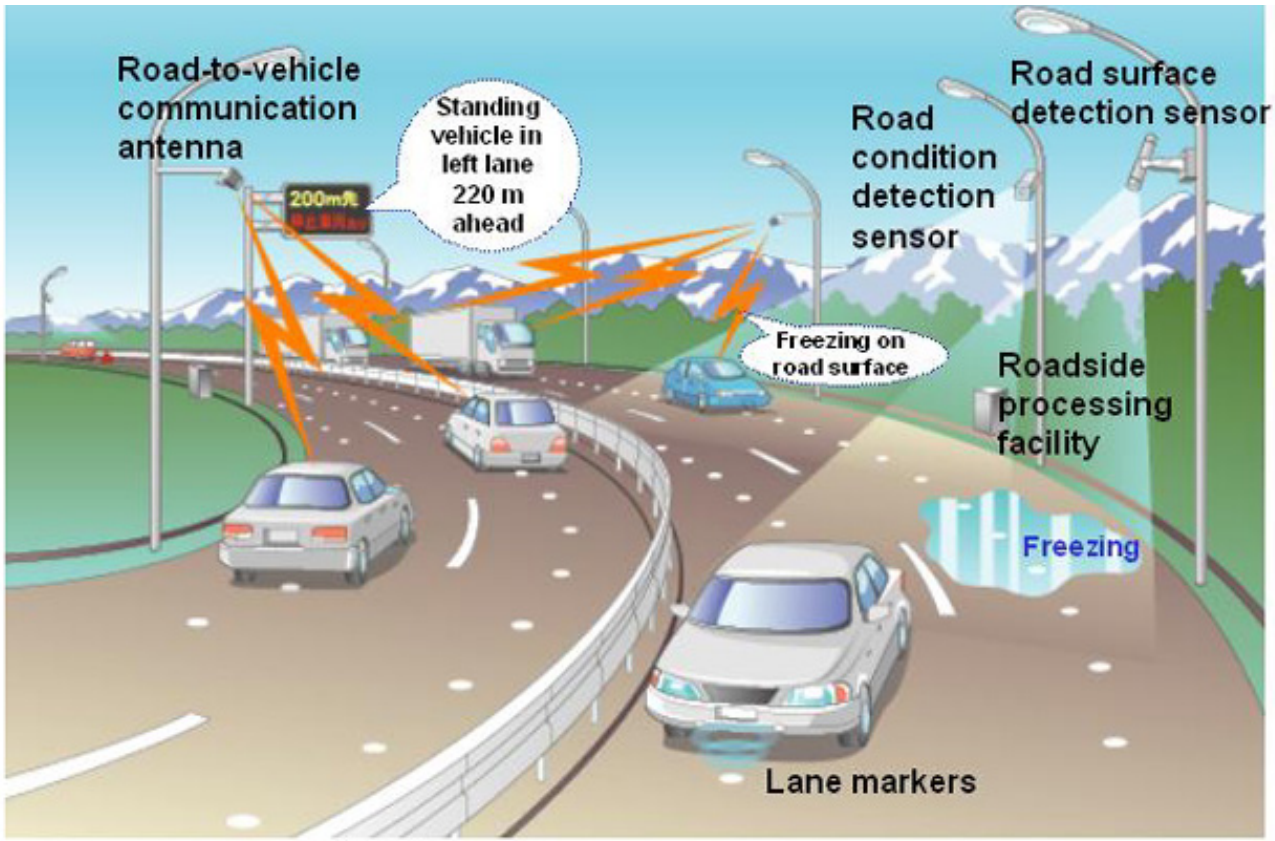


Spectrum Sharing- MAC Layer

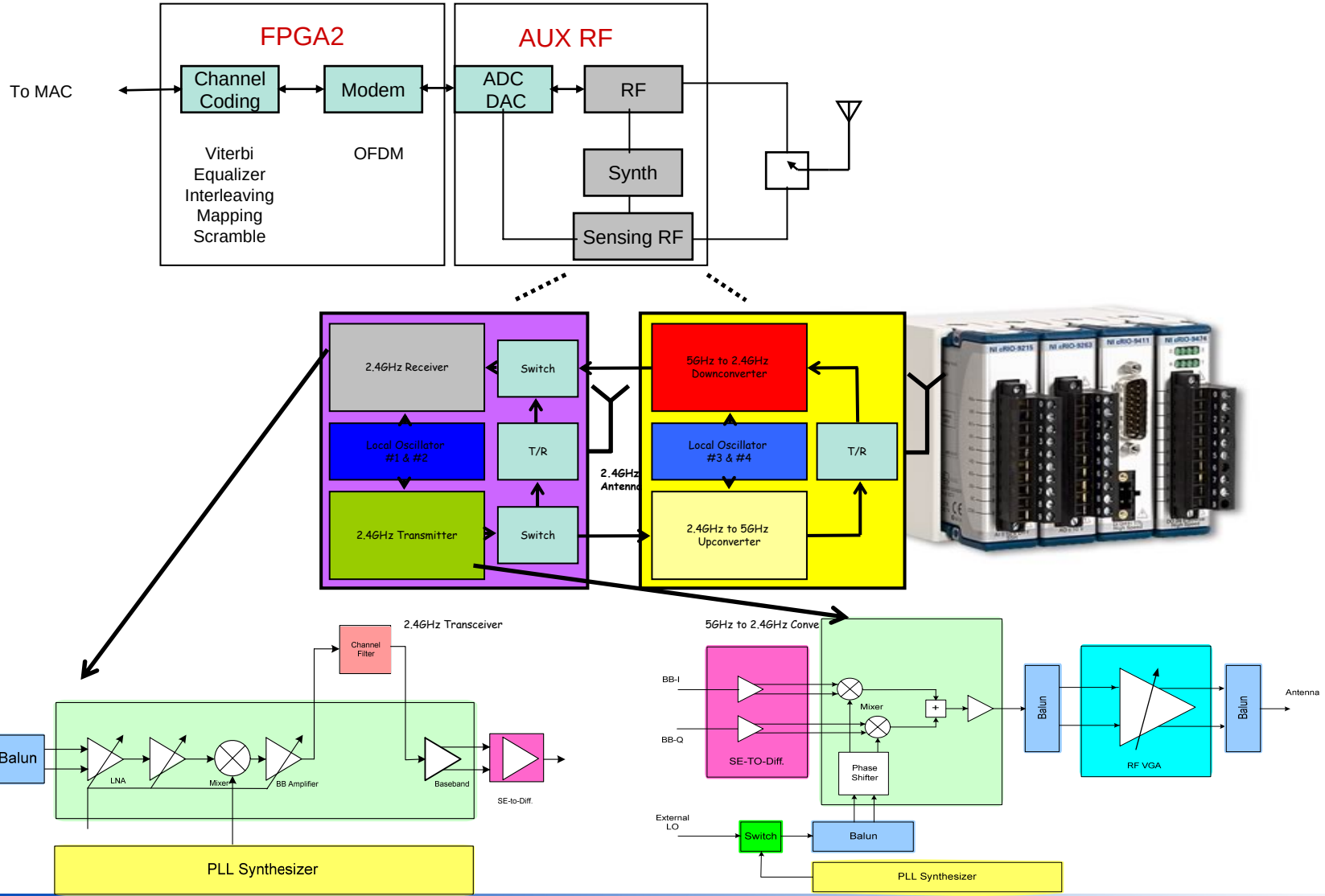
- An intelligent MAC based on “Bandit Theory”



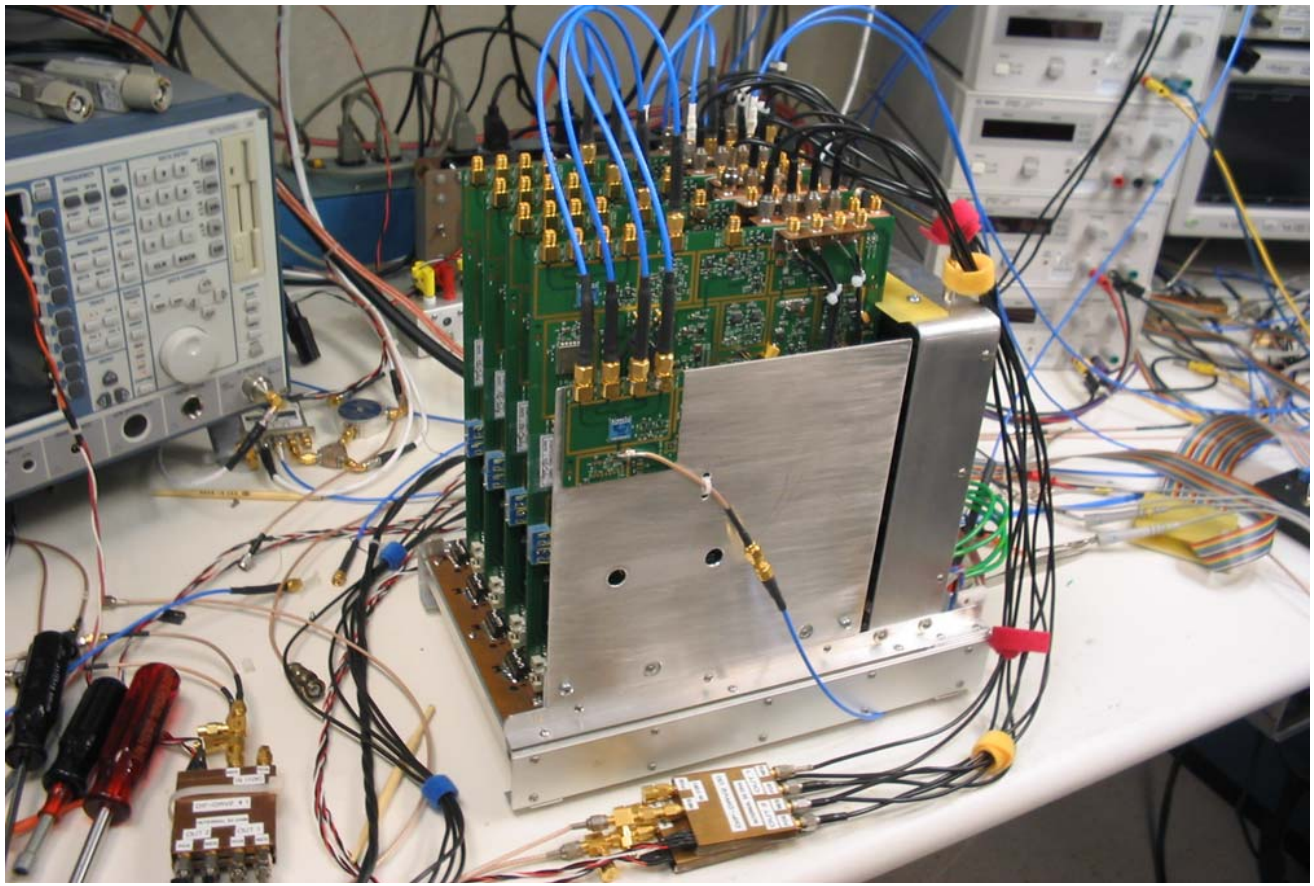
DSRC- Vehicle Communications (AHS)



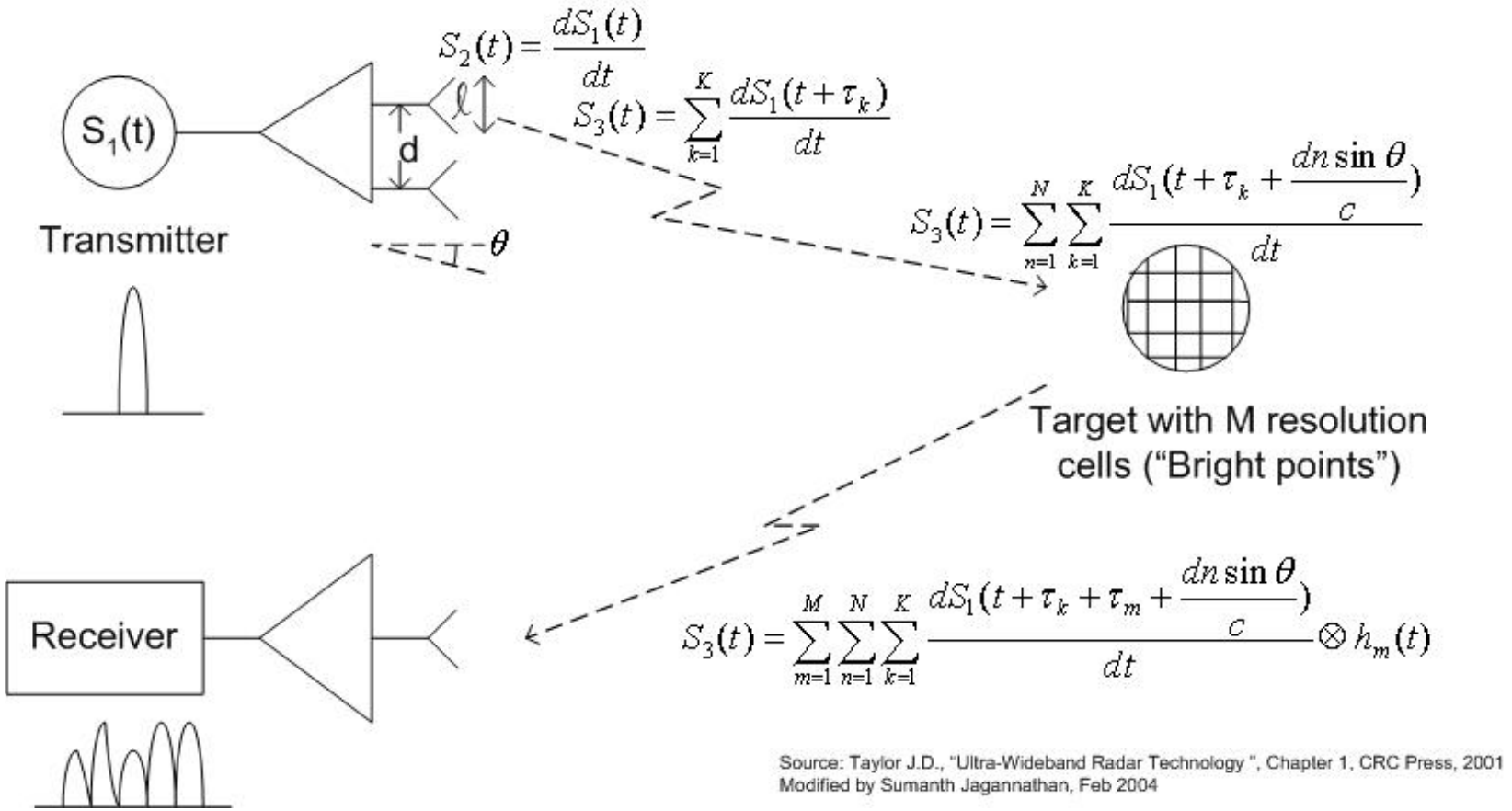
Intelligent Radio for DSRC



4G Platform at UC Berkeley!



UWB Radar versus Conventional Radar



Source: Taylor J.D., "Ultra-Wideband Radar Technology ", Chapter 1, CRC Press, 2001
Modified by Sumanth Jagannathan, Feb 2004

Conclusion

- Ubiquitous smart connectivity is bringing about irreversible changes in our lives at Individual and social levels

- Enabling technology for this revolution transcend single area of research ranging from semiconductor and MEMS to network design

- A Close collaboration between different disciplines in research centers, which is facilitated by CITRIS at UCB is indispensable

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Thank You