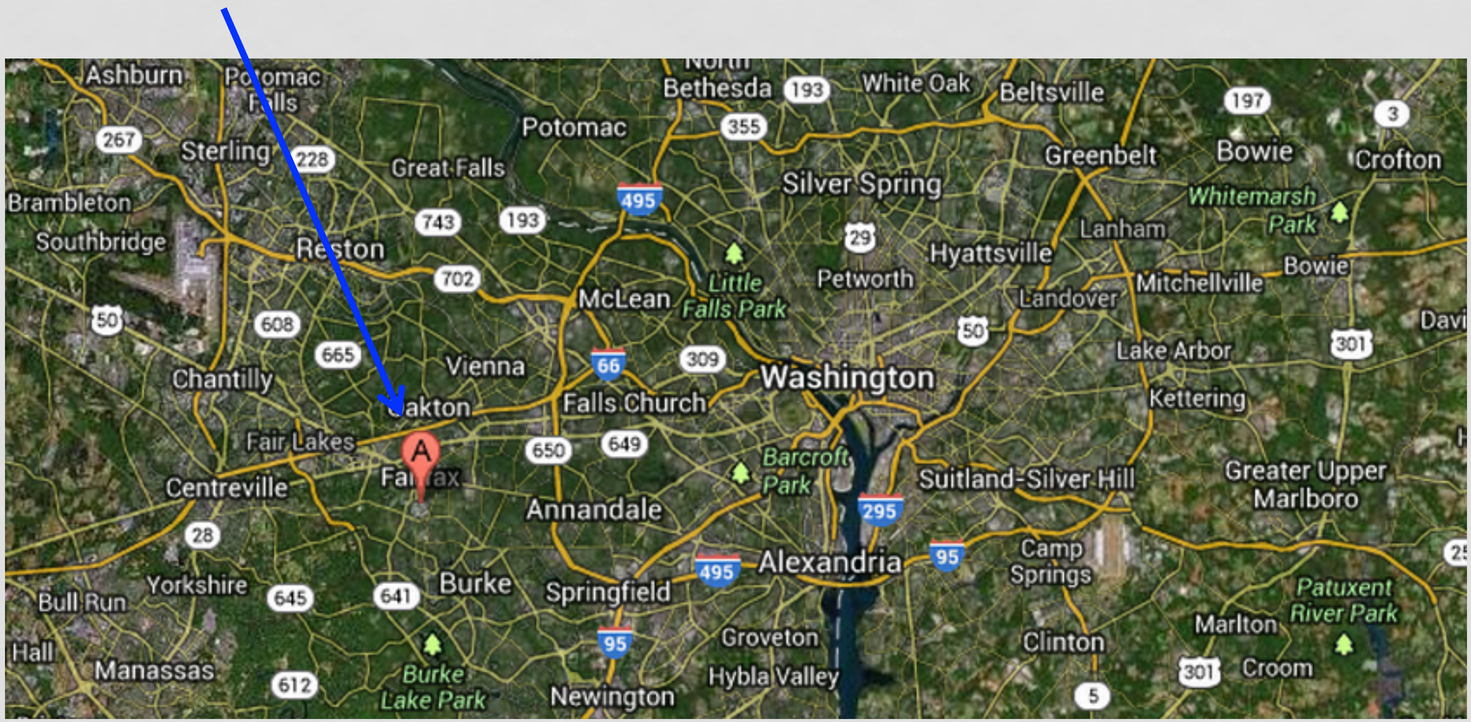
THINGS IN THE INTERNET

DR. ROBERT SIMON

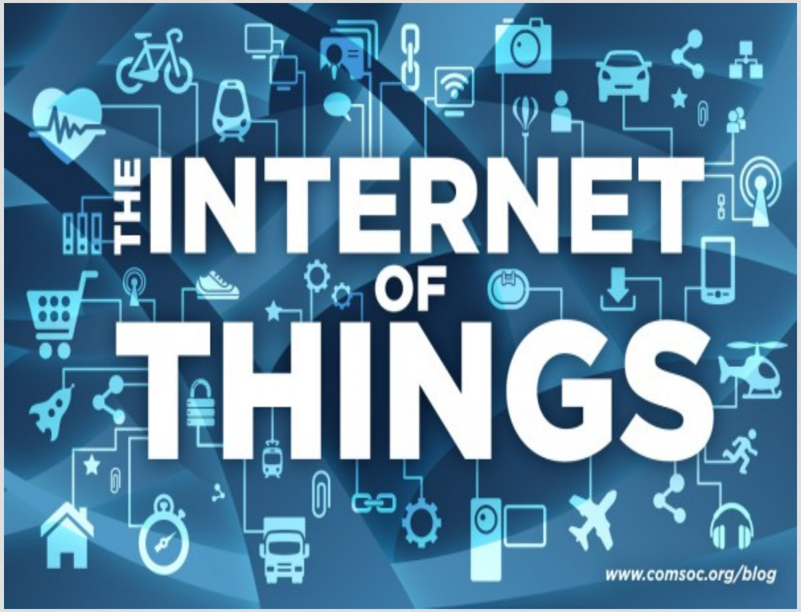
GEORGE MASON UNIVERSITY

- GMU is part of Virginia's public university system
- Attended by roughly 33,000 students
- Located approximately 20 miles west of downtown Washington D.C.



WHAT I AM GOING TO TALK ABOUT

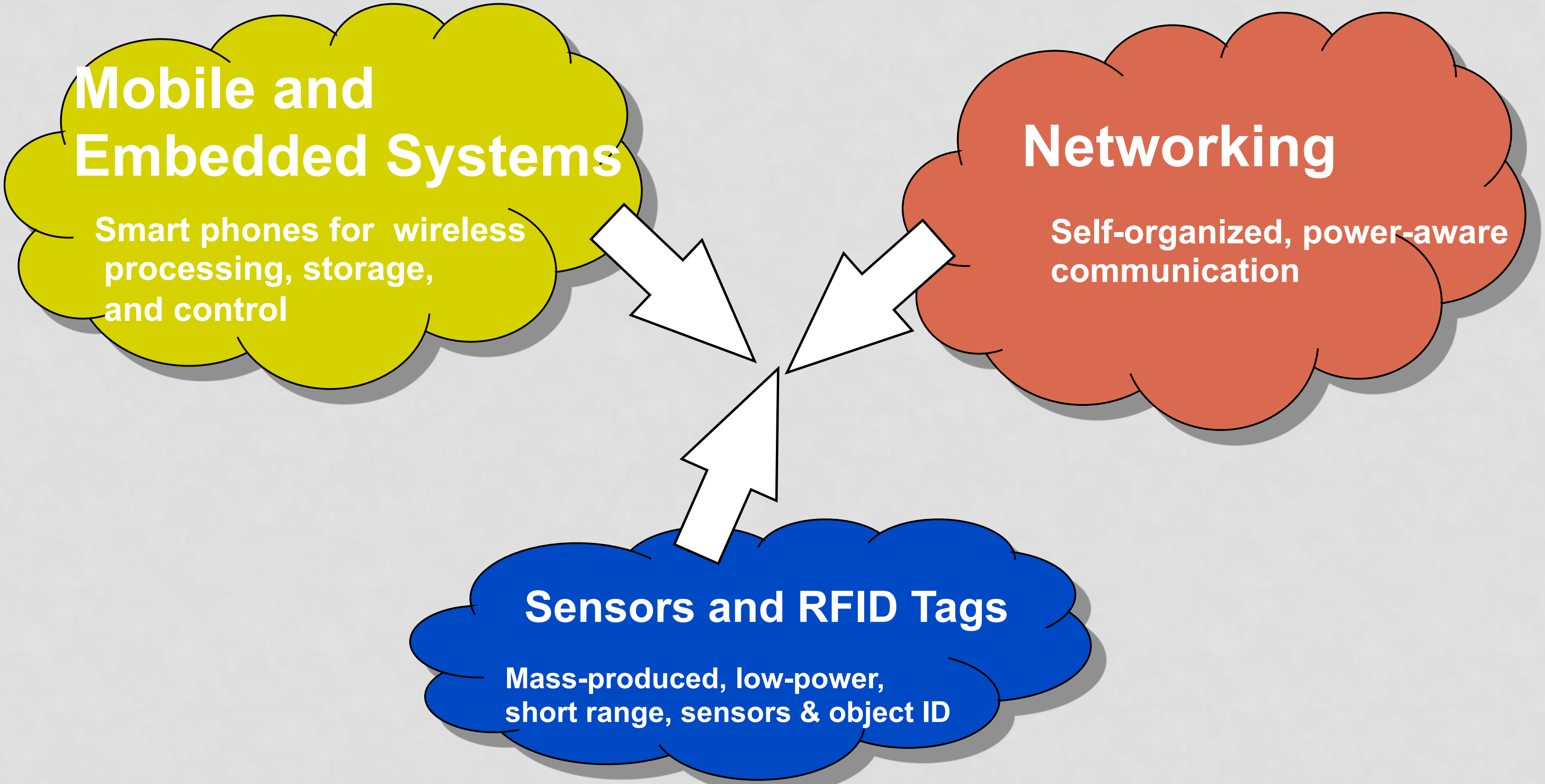
- The most recent hype from the world of technology is the "Internet-of-Things."
- Means many different things to many people.
- But IoT *does* represent a rapidly emerging technological convergence
- My talk: from a Computer Science perspective
  - Is anything new?
  - Hint: yes



INTERNET OF THINGS: A FUNCTIONAL VIEW

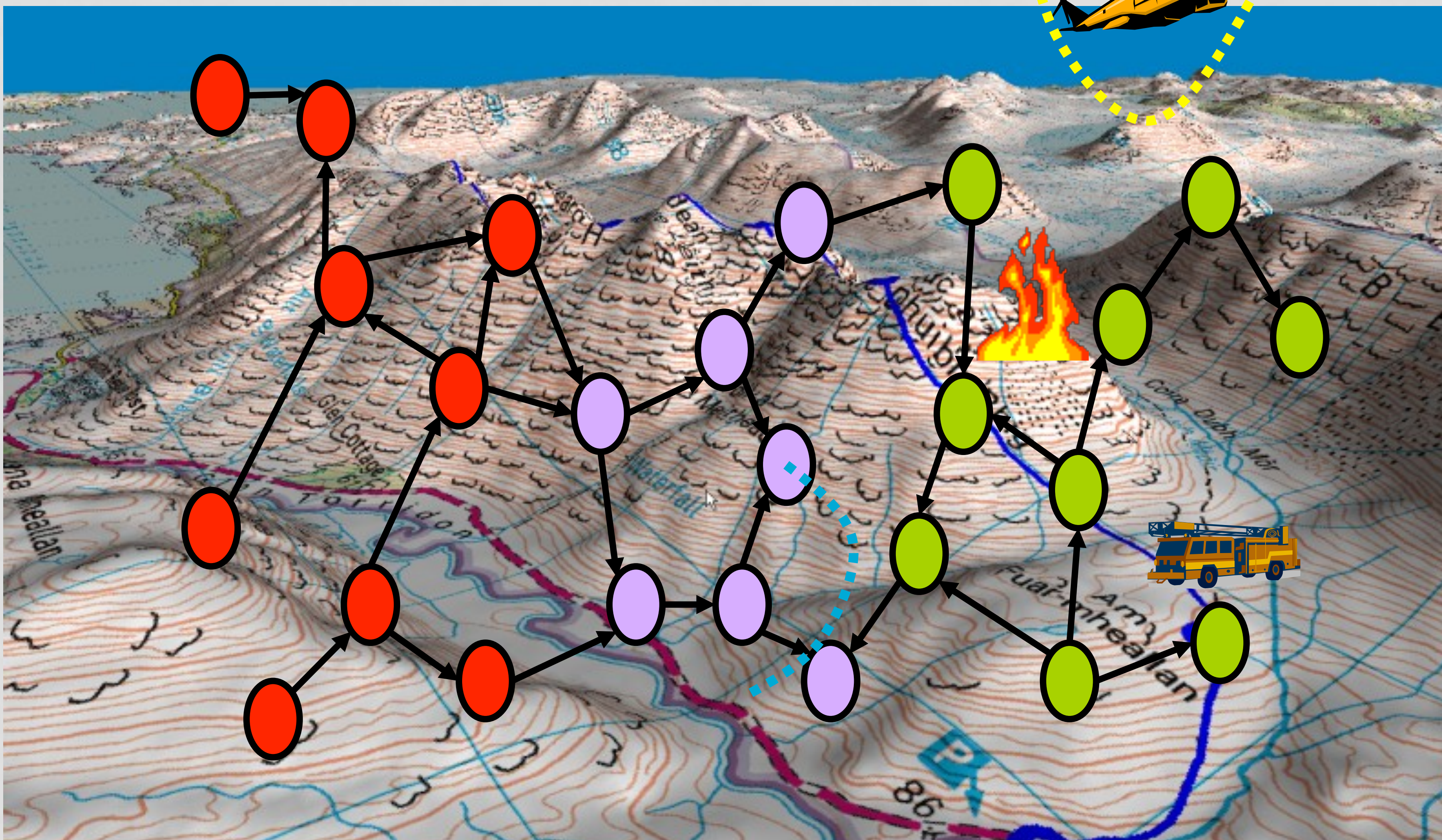
Devices monitor and interact with other devices and humans

Humans and devices interact and collaborate

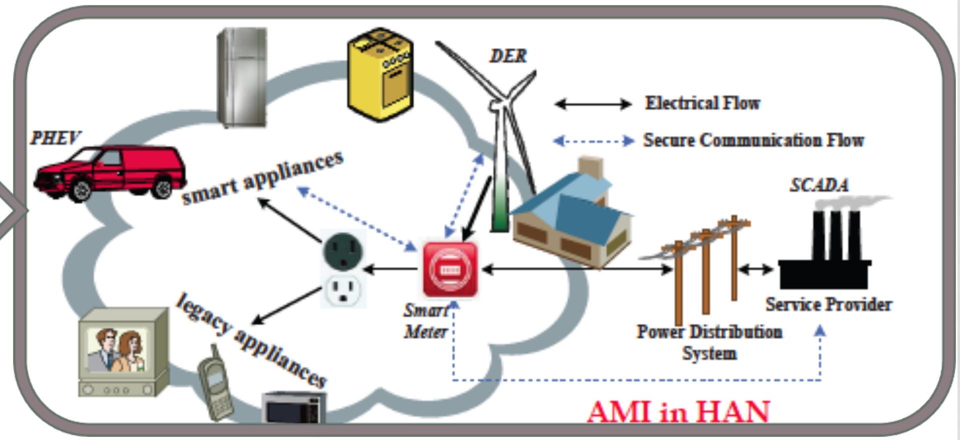


Devices monitor and interact with the physical world

IOT APPLICATION: MONITORING INACCESSIBLE AREAS



IOT APPLICATION: SMART GRID



- Enables real-time pricing decisions by consumers and affords utilities greater control over their own systems

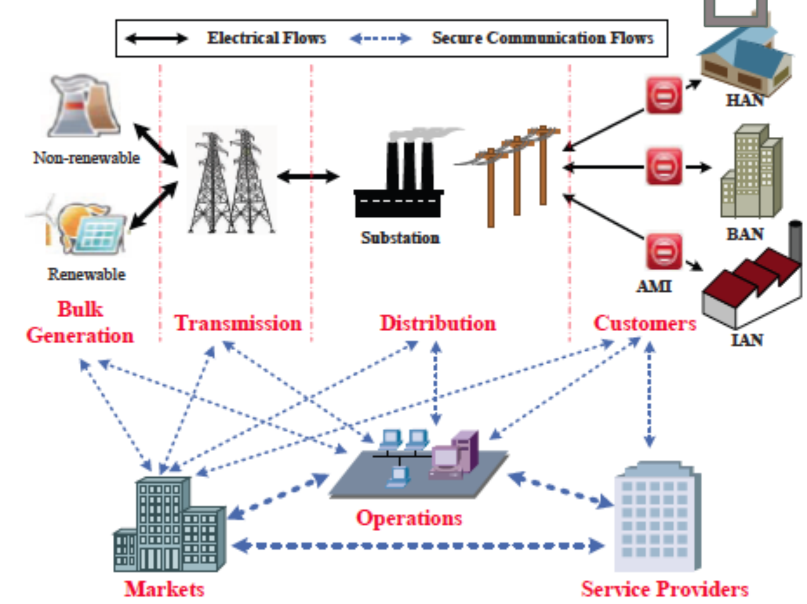
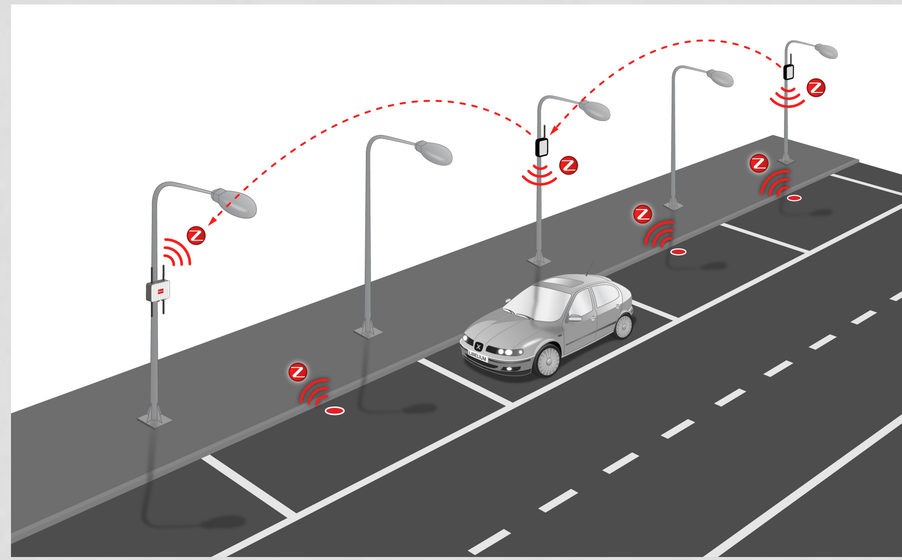


Fig. 1. NIST reference model for the smart grid [4]

IOT APPLICATION: SMART BUILDINGS AND CITIES

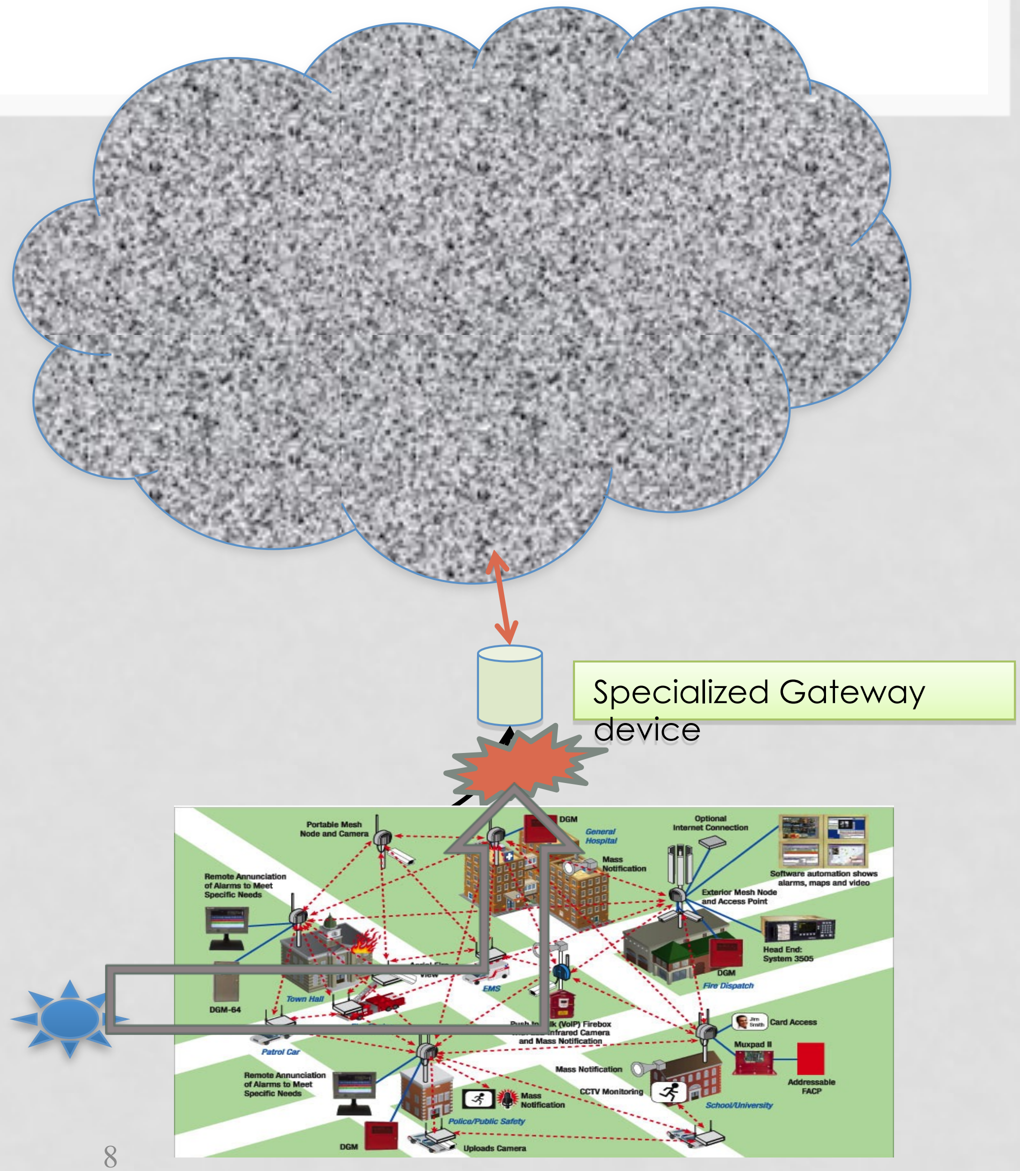


Libelium: Smart city in Santander, Spain

The EnOcean alliance: Energy Harvesting for smart buildings with installation of 250,000 buildings

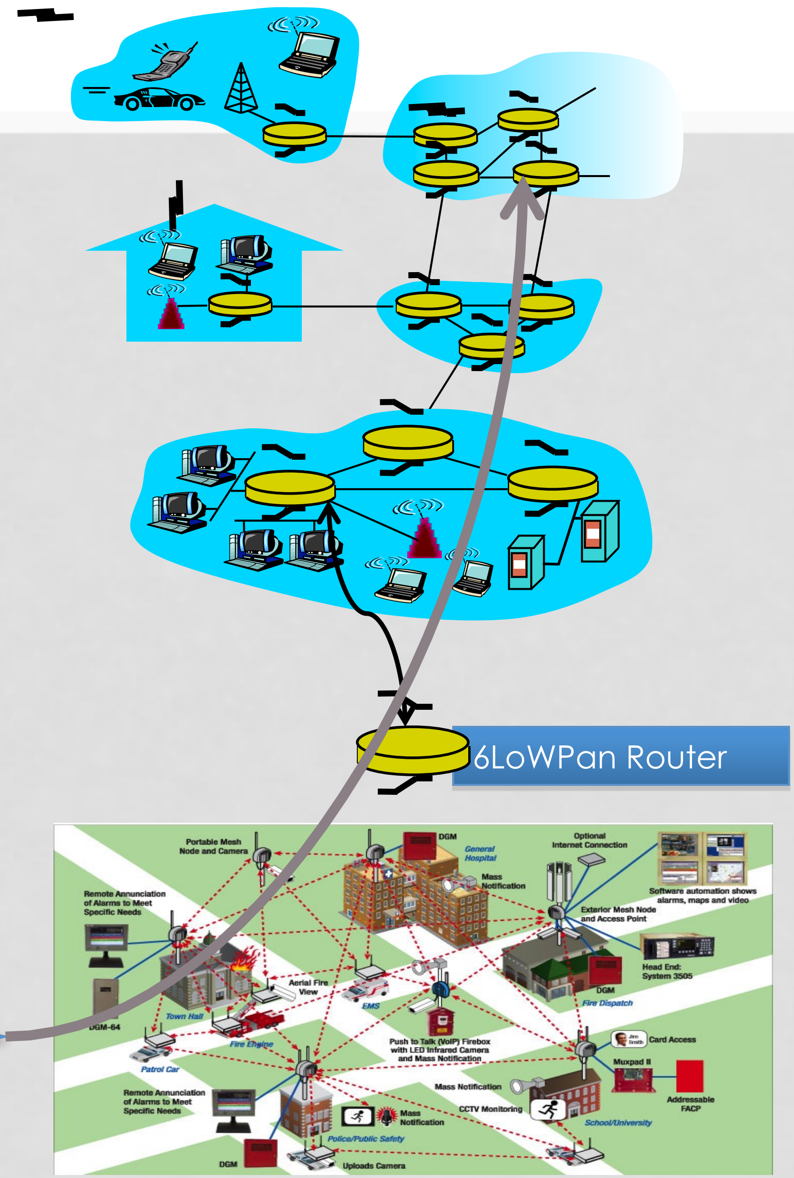
TRADITIONAL SYSTEMS

- Traditional Scenario
- Connectivity to the Internet through the use of specialized gateway devices and protocols.



ARCHITECTURAL PERSPECTIVE (2)

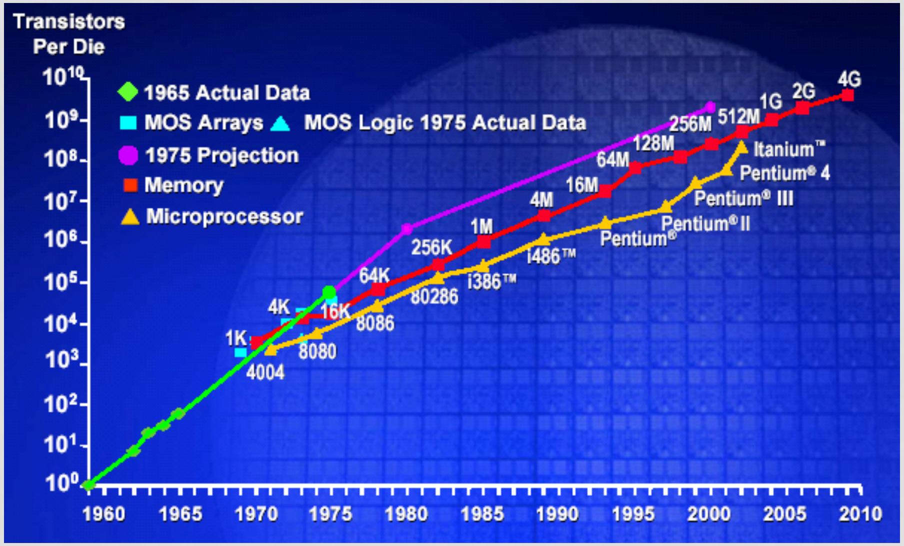
- The emergence of IoT standards such as 6LoWPAN for IP communication over low-power radio links dramatically eases integration of large networks and enables interoperability between low-power devices and existing IP devices
- **Leads to an IP address on everything**

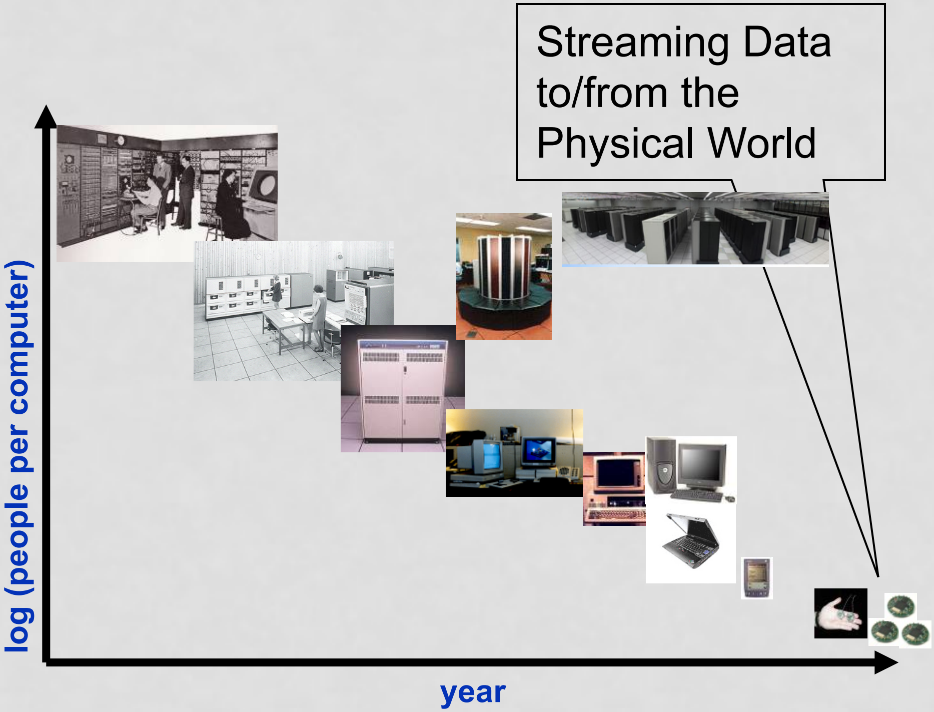


WHY NOW?

- Moore's Law
  - Advances in hardware doubles power roughly every 18 months or so
- Bell's Law
  - New computing class every 10 years

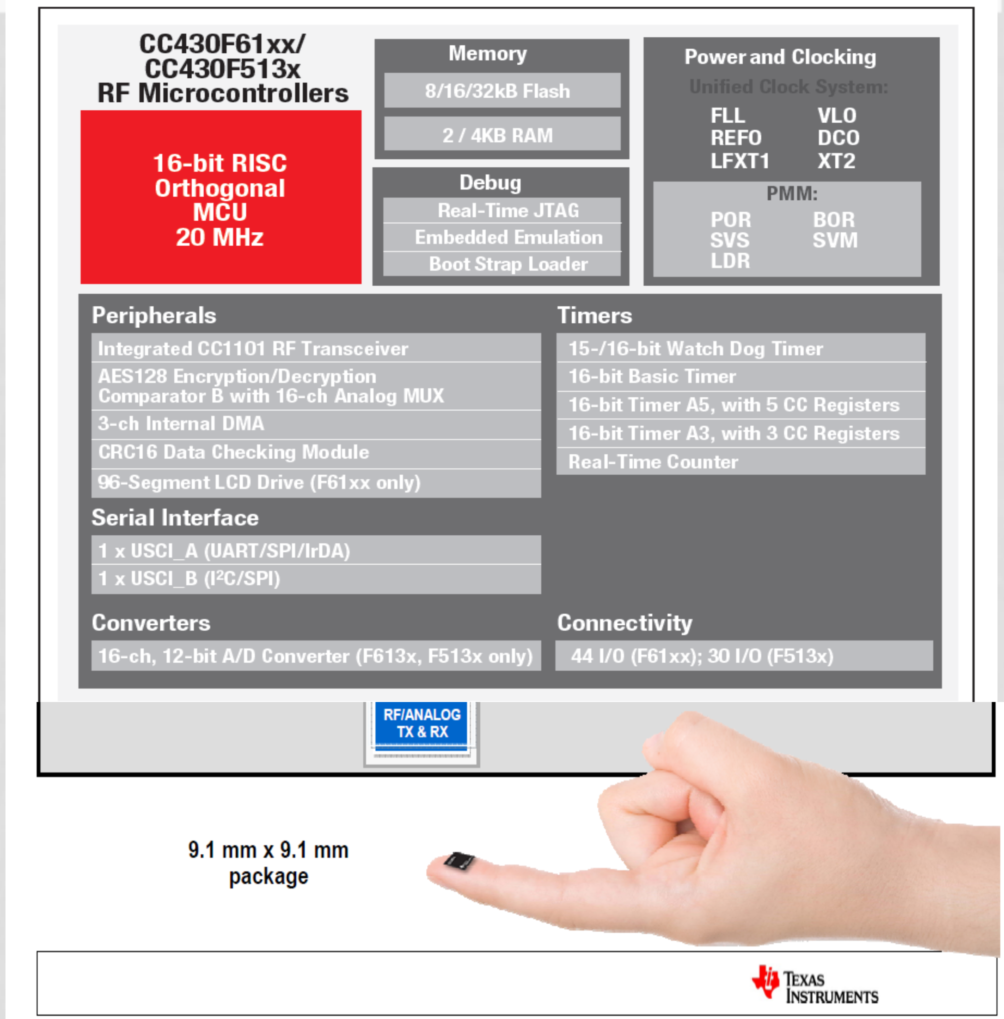
Transistors





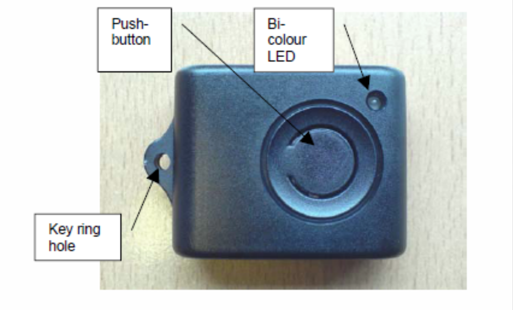
IOT DEVICE: WIRELESS SENSOR NETWORKS

- Designed for *physical sensing, actuator control, local processing and wireless communication*
- Devices combine sensors, cpu, communication, power supply in a small package called a "***MOTE***."
- Sensors include temperature, heat, light, chemicals, etc.
- **The motes are the infrastructure**



TWO SMART RIFD COMMERCIAL EXAMPLES

- Jennic *Coin Cell Powered Active RFID Tag*
  - 802.15.4 Ad hoc networking
  - *http://www.jennic.com/files/support_documentation/JN-RM-2055-JN5148-Coin-Cell-Active-RFID-Tag.pdf*
  - Motion detection using an acceleration switch
  - CR2032 210-mAh coin cell powered (or similar)
  - Reservoir capacitors for pulsed operation
  - Optional serial EEPROM for Tag context storage
  - Optional low-power 32-kHz precision reference crystal



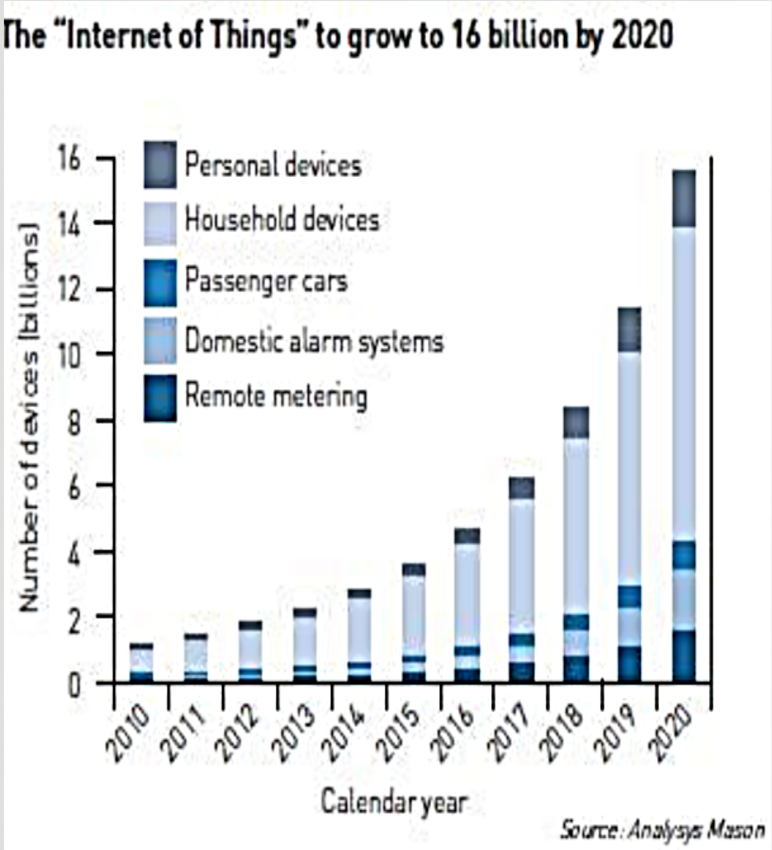
KSW Technic *VarioSense* Hybrid Power Tag

–*http://www.ksw-microtec.de*

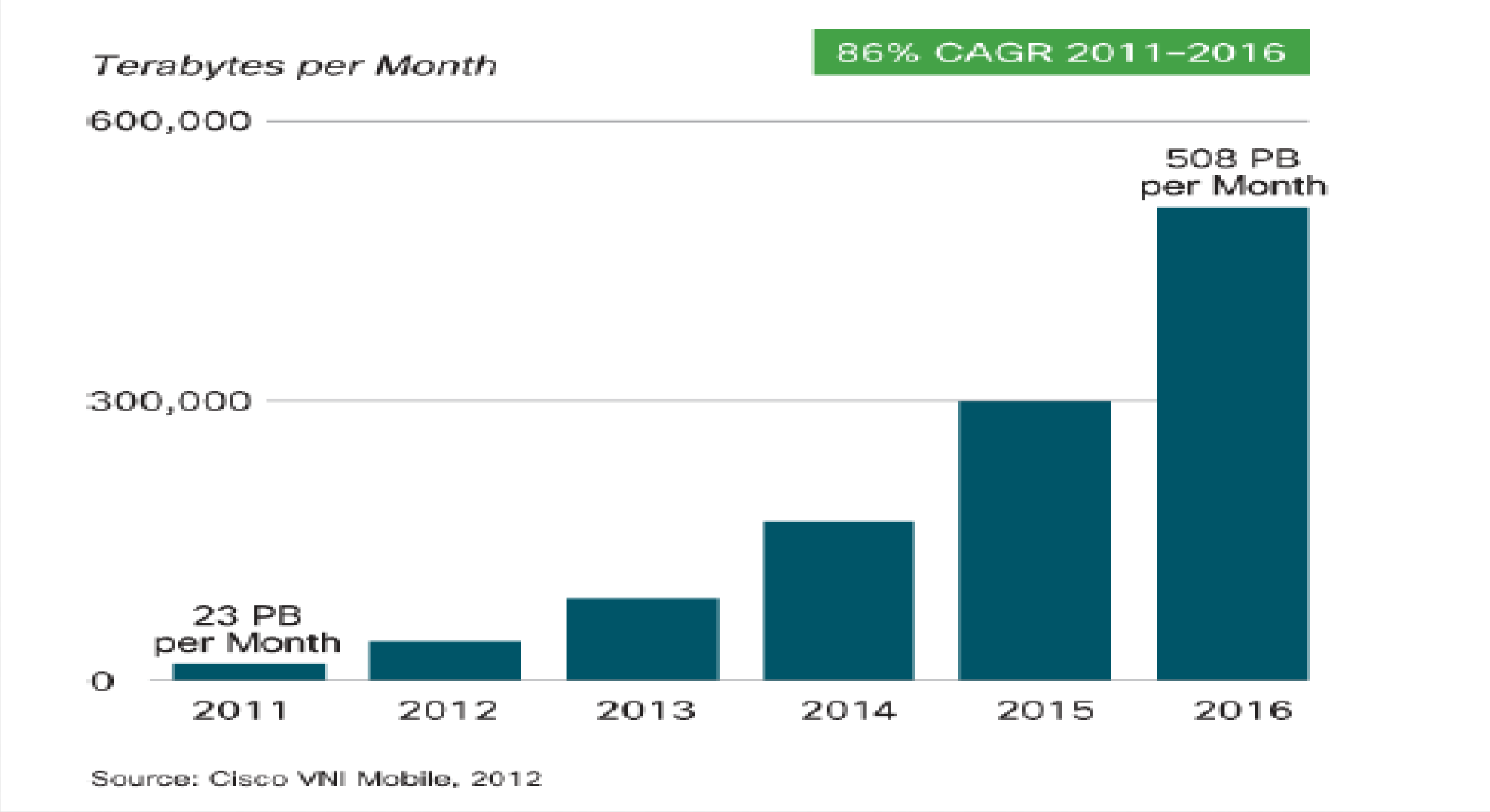
integrated circuit (IC)	KSW-VarioSens® Chip
operating frequency	13,56 MHz
air interface protocol	ISO 15693-3
memory	7680 bit EEPROM splited memory for customer data and monitored temperatures with time stamp 512 bit system memory
data protection / security	3 level password
data retention	longer than 10 years according to IC specification
temperature range / accuracy	-5°C to +30°C with ±1 K (typical ±0,3 K) -20°C to +50°C with ±1,75 K (typical ±0,6 K)
operating environment	-20°C to +50°C (limited mechanical stress and reduced battery lifetime at temperature below -5°C); higher than 30% relative humidity
timer accuracy	better than ±5%
battery life time	max 1 year (battery life time depends on the operation condition)

MARKET PREDICTIONS

- Today, approximately 3B PCs, tablets and smart phones are connected to the Internet
- In 2020, it is conservatively forecasted that 16B IoT devices will be connected to the Internet



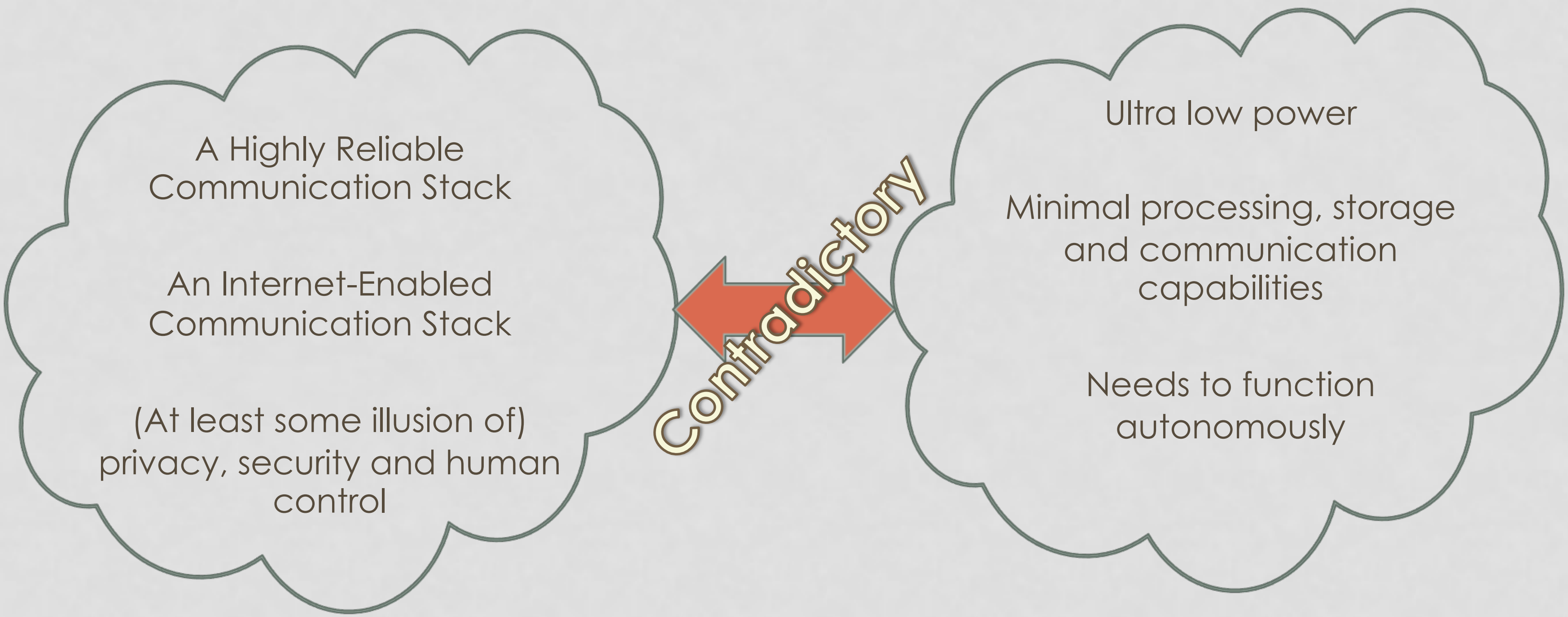
MACHINE-TO-MACHINE TRAFFIC INCREASE 22-FOLD BETWEEN 2011 AND 2016



Where have all the humans gone?

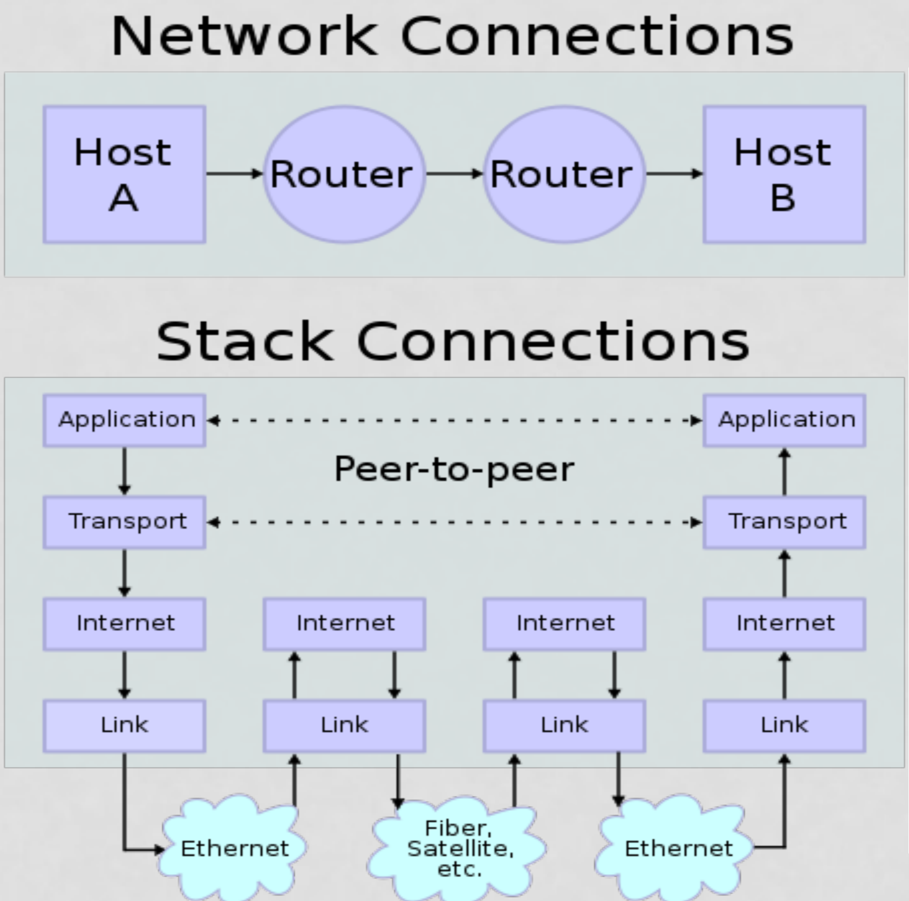
WHAT ARE THE RESEARCH CHALLENGES? (A SYSTEMS PERSPECTIVE)

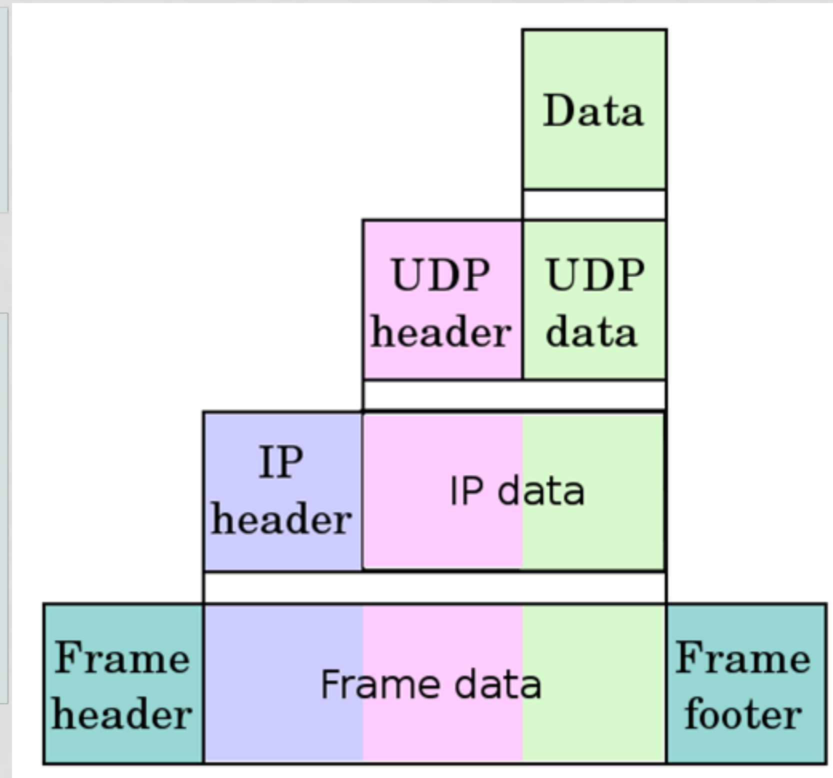
IoT Application Requirements | **IoT System Realities**



SECURITY AND PRIVACY

NETWORKS INCLUDING IOT ARE BUILT USING A LAYERED MODULAR APPROACH





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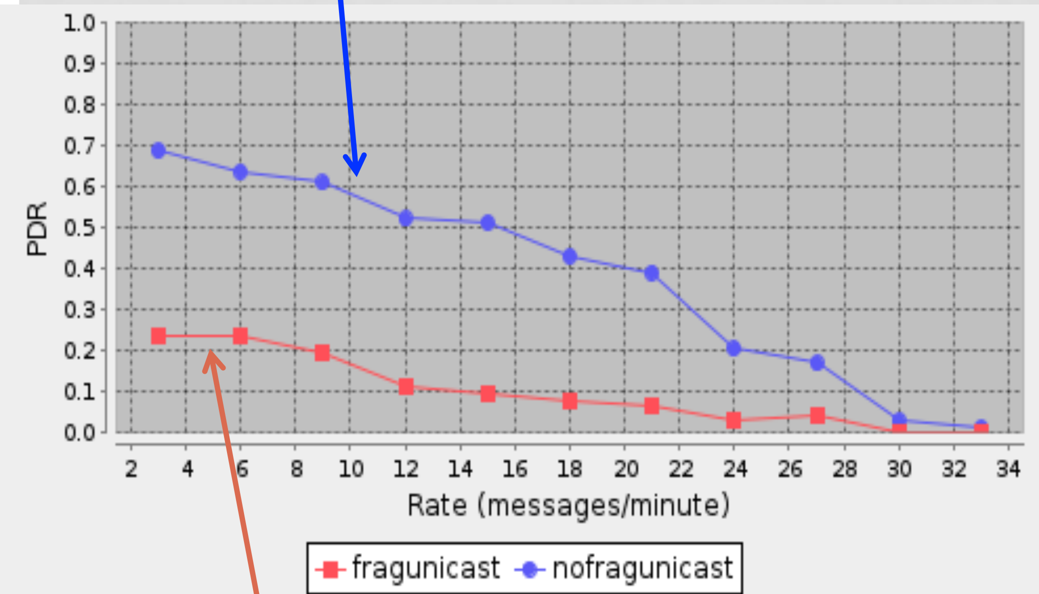
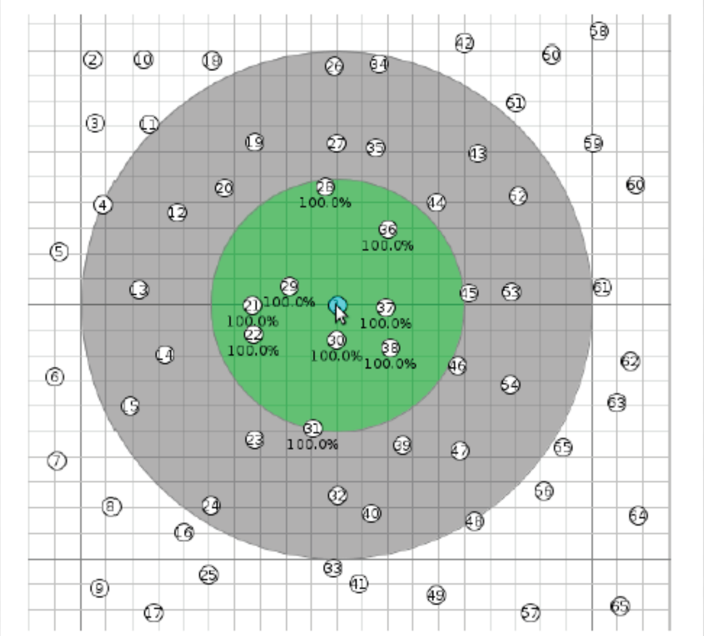
ROUTING IN GEO-LOCATED AND MOBILE IOT APPLICATIONS

What we expected

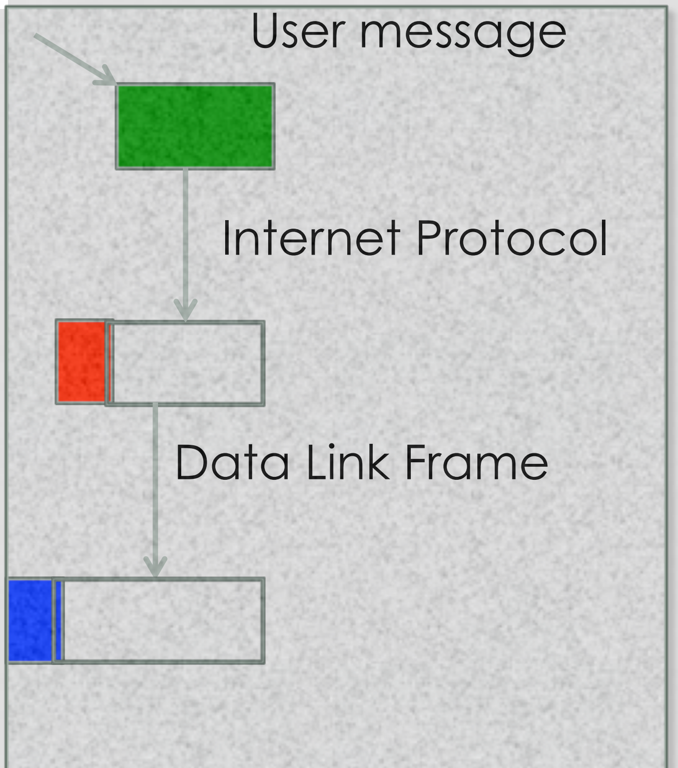




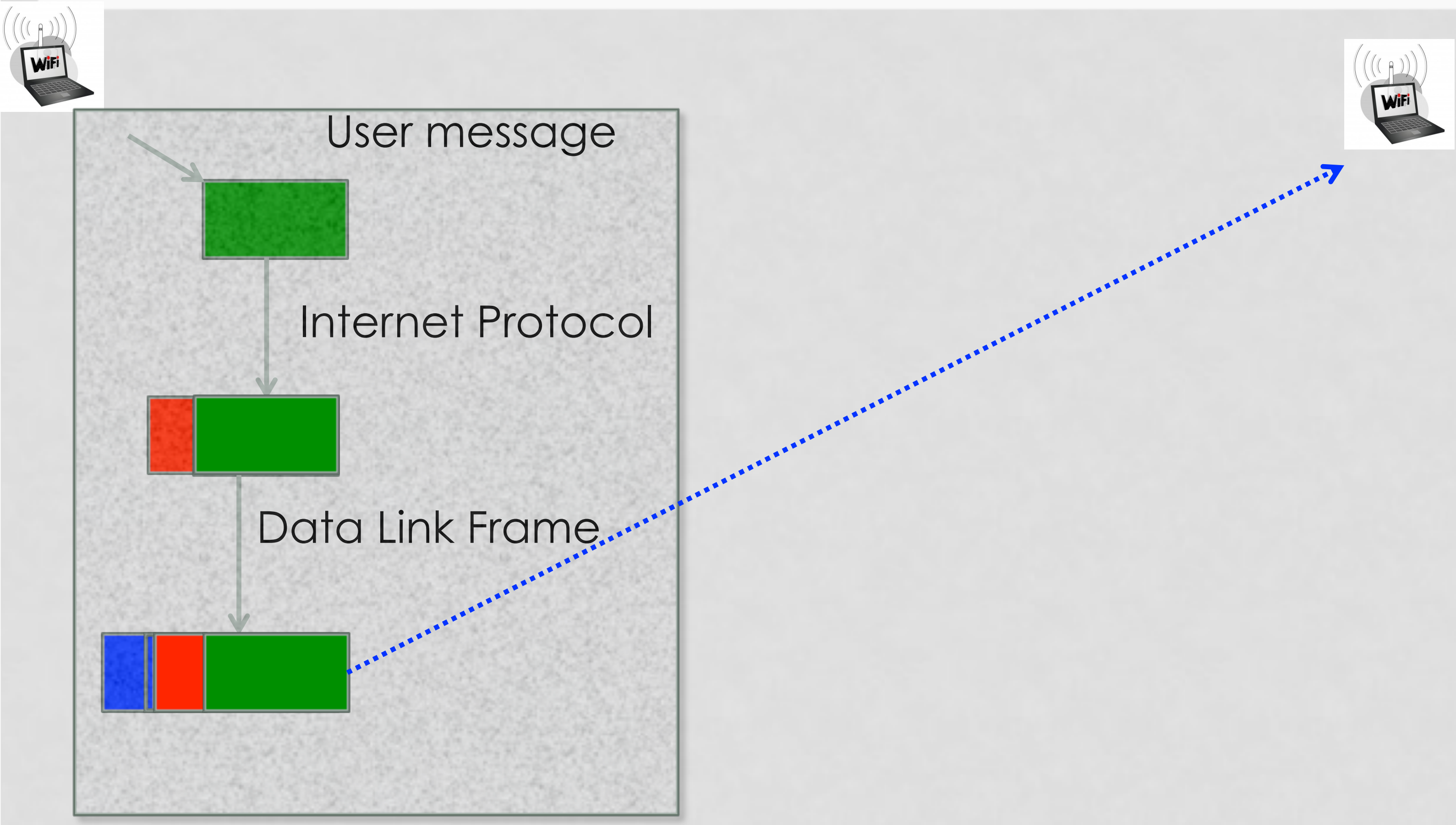
What we got

Work with James Pope, Andrew Bovill and Kevin Andrea

PACKET TRANSMISSION

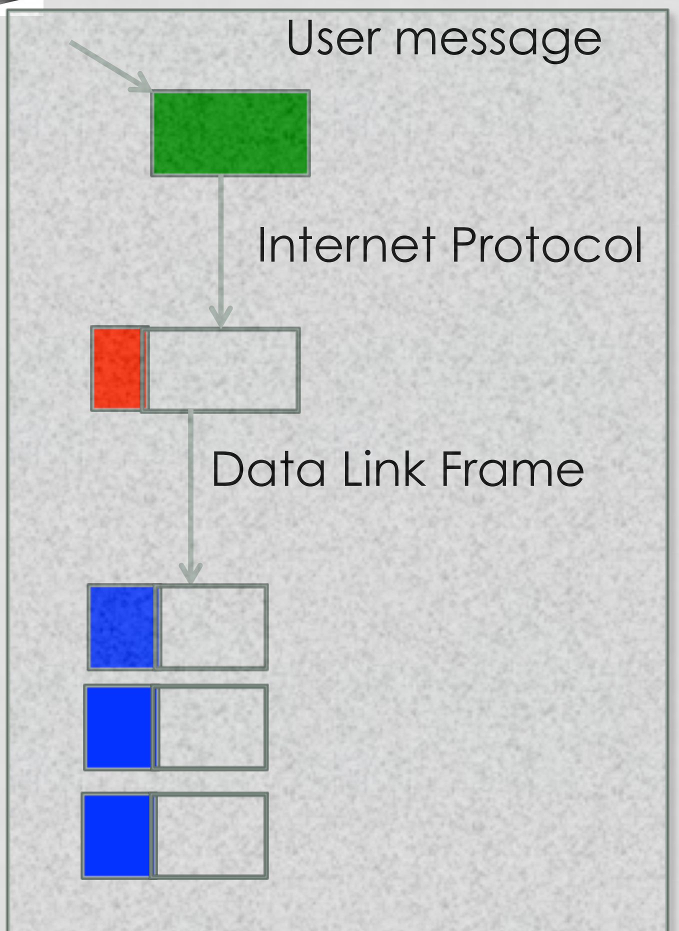


PACKET TRANSMISSION



Successful message delivery

FRAGMENTED PACKET TRANSMISSION



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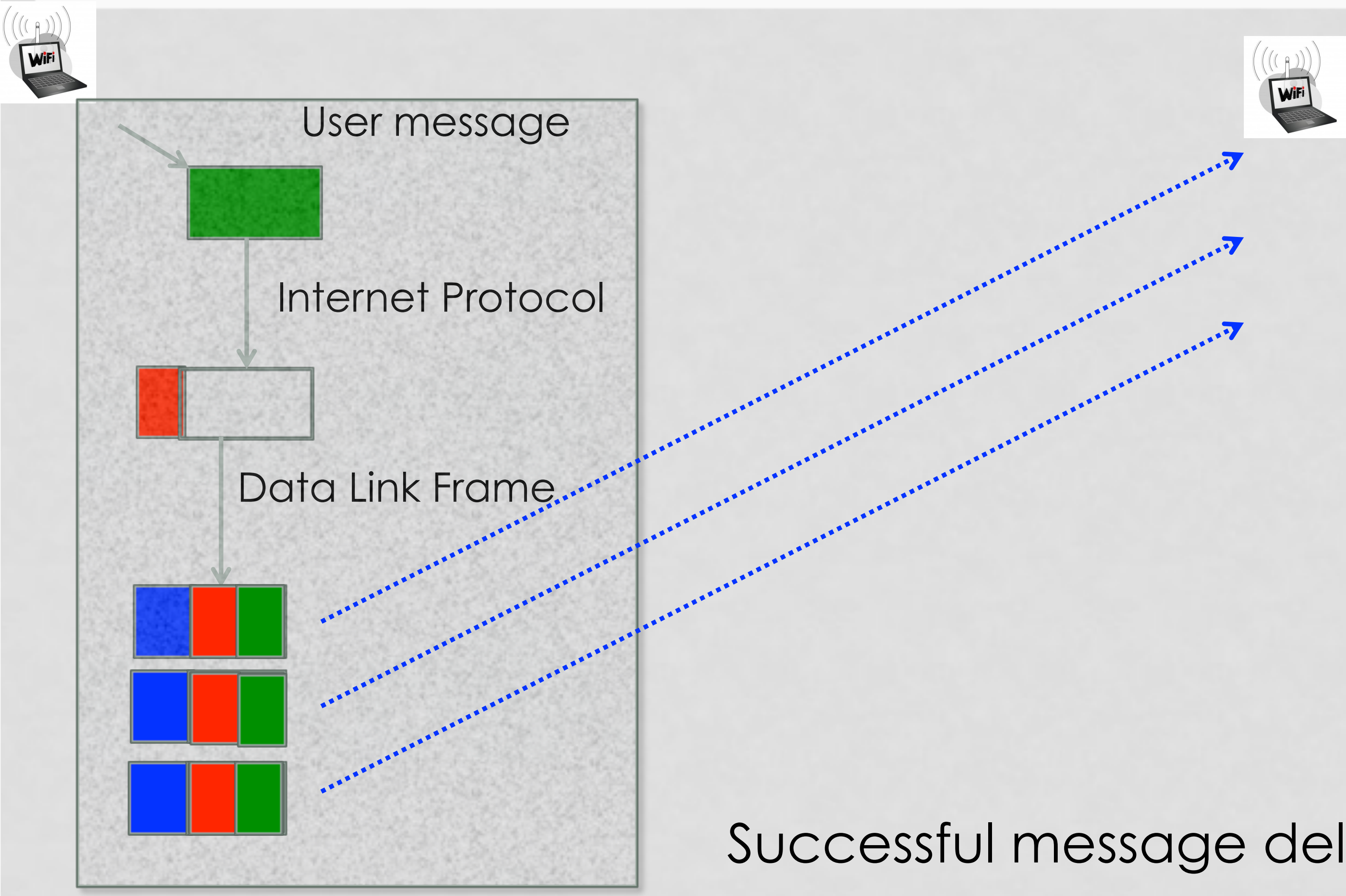

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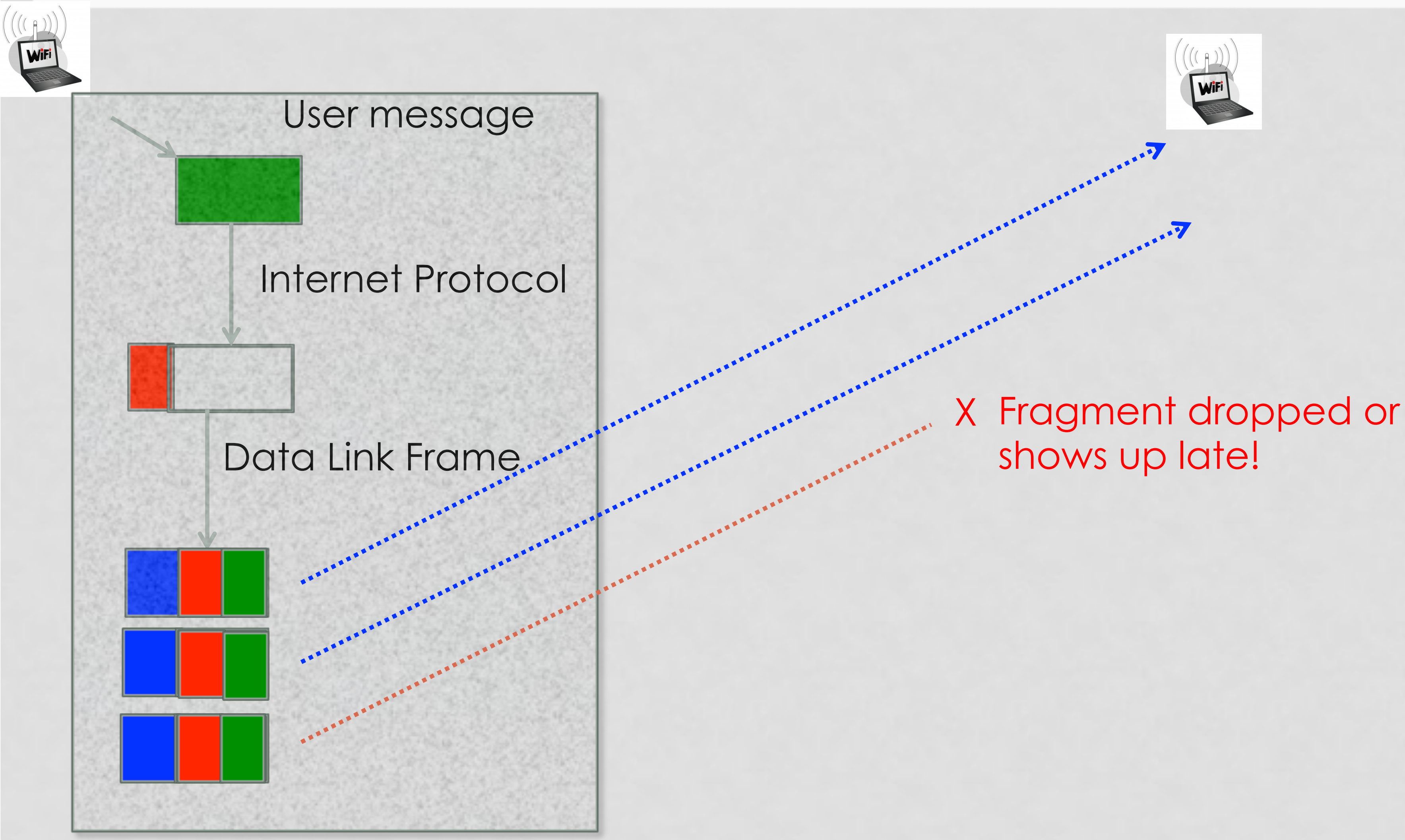
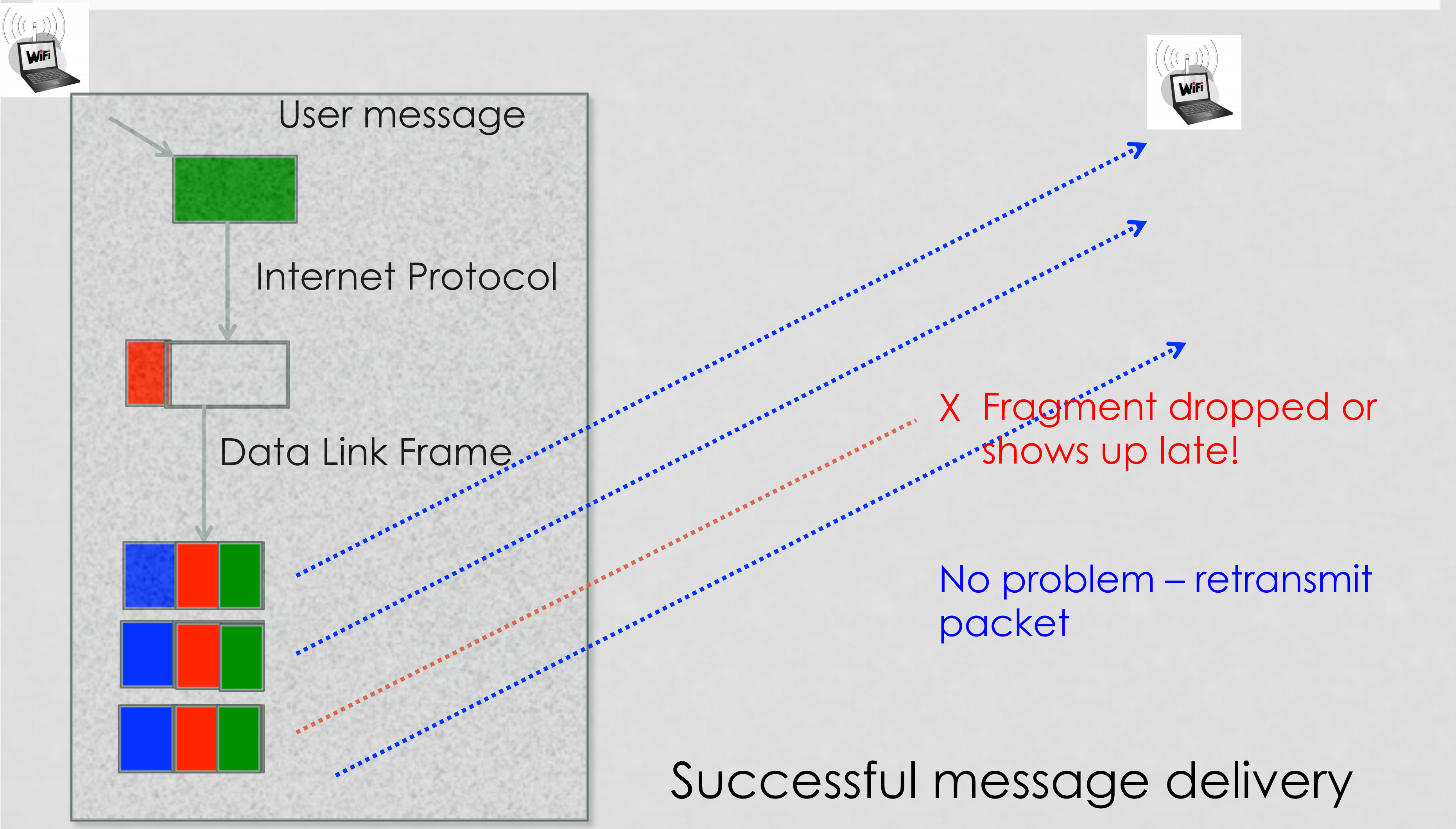
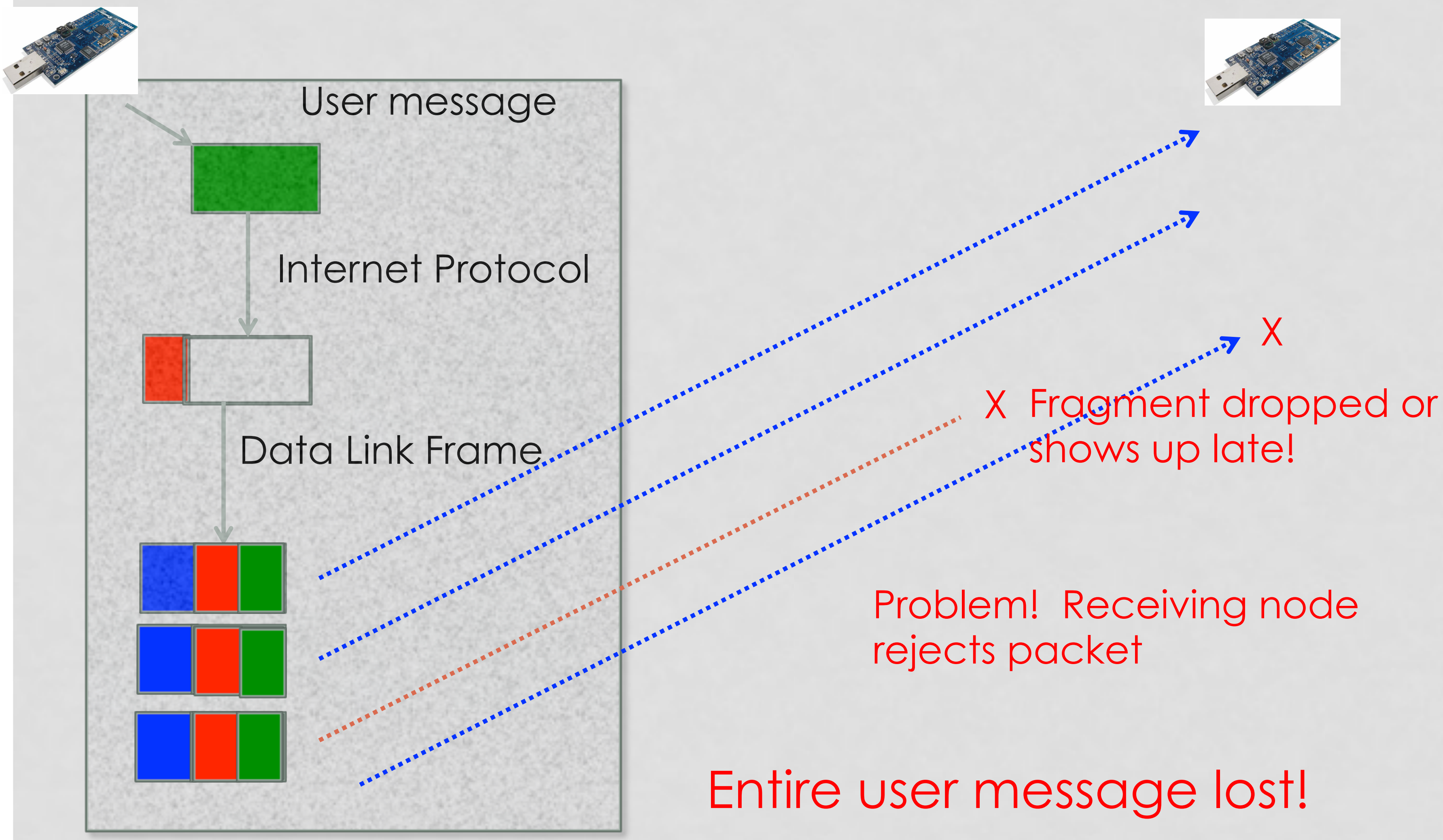


FRAGMENTED PACKET TRANSMISSION

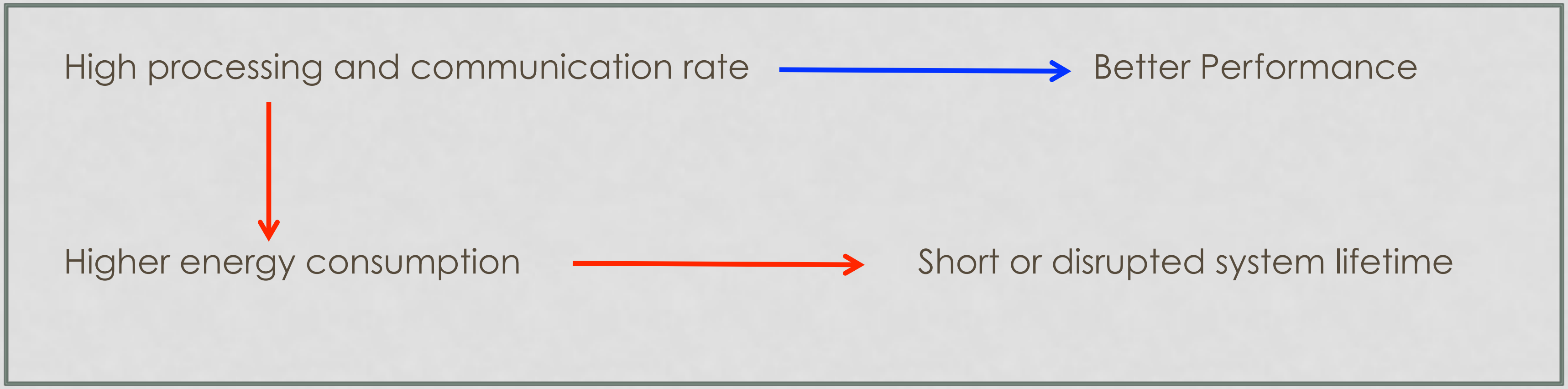


IOT FRAGMENTED PACKET TRANSMISSION



ENERGY RESTRAINTS IN MISSION-CRITICAL IOT SYSTEMS

- Minimizing energy consumption is good
- But IOT systems will increasingly be pushed into performance sensitive applications
- Nasty cycle



Work with Hakan Aydin, Bo Zhang, Maraym Bandari and Arda Gumusalan

WHAT CAN BE DONE?

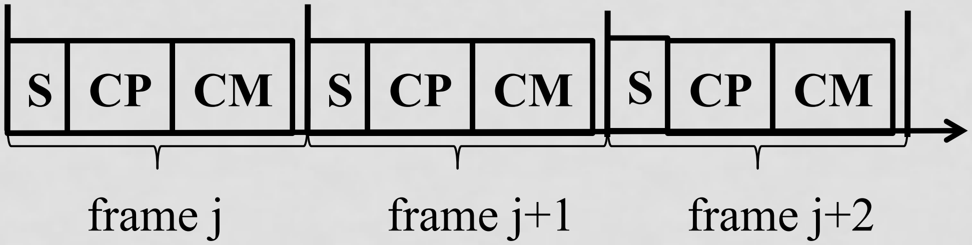
- Use hardware techniques previously overlooked or ignored
- For instance, combine Dynamic Voltage Scaling(DVS) with Dynamic Modulation Scaling (DMS)
  - Develop algorithms using techniques in "hard" real-time systems

Obtain a better understanding of IOT requirements

- Increasing the data or communication rate does not necessarily increase the benefit to the application
  - Tradeoff application utility with system performance

TASK MODEL

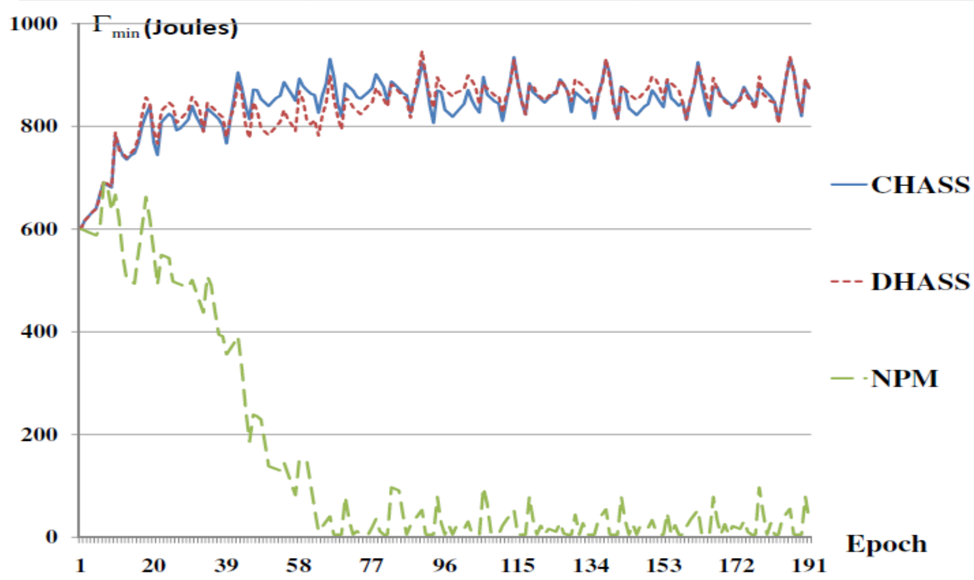
- Three basic operations: ***sense (SN)***, ***compute (CP), communicate (CM)***.

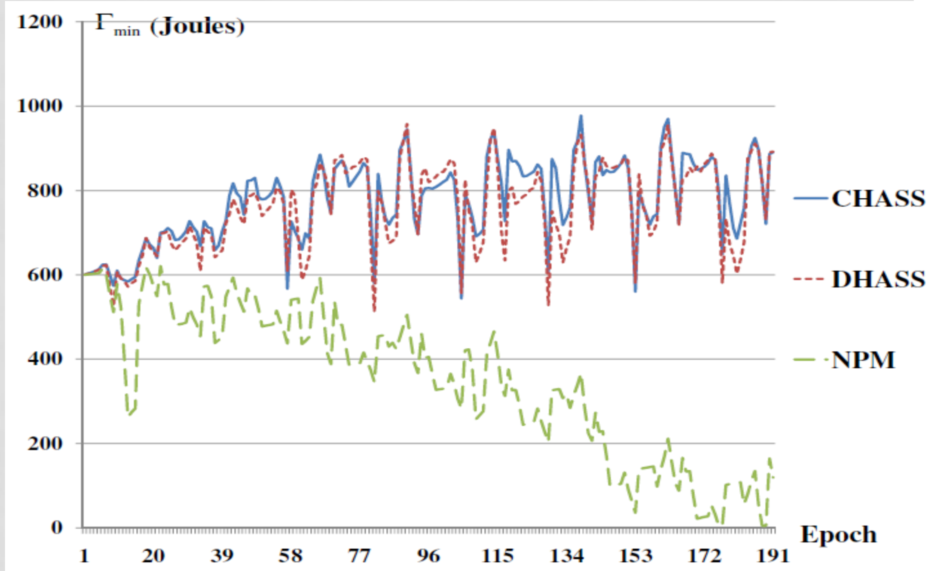


- Precedence constraints
- Computation workload: ***C*** (cpu cycles). Communication workload: ***M*** (bits).
- Tasks are executed periodically within ***time-bound frames***..
- Maximum task execution time in a frame: $$t^{exe} = t^{sen} + \frac{C}{f} + \frac{M}{d}$$

ENERGY-HARVESTING AWARE DVS AND DMS SPEED SELECTION

- Formulated energy reserves, DVS and DMS as a joint delay and processing function
- Modeled system performance requirements as a real-time task
- Developed a set of optimal speed settings for all nodes in the system





UTILITY MAXIMIZATION

- Aimed towards sensing-based IoT applications with fixed energy budgets
- Need to quantify application utility
  - It is a concave function of the sensing rate of each node
  - Notice: all other system activities are overhead
  - Formulated the utility maximization issues as a non-linear optimization problem constrained by an energy budget, minimum per node sensing required and overall system capacity
  - Proved the existence of an optimal algorithm (Best paper award, ACM MSWIM 2011).

CURRENT WORK IN THIS AREA

- Supporting both mobile and fixed base stations commanding IOT systems
- Automatically geo-locating IOT IP address management
- Extending hard real-time model for probabilistic workload modeling
- Multi-channel network coding techniques.

THANK YOU!
QUESTIONS??