Computer Networks

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Why am I here?

My goal:

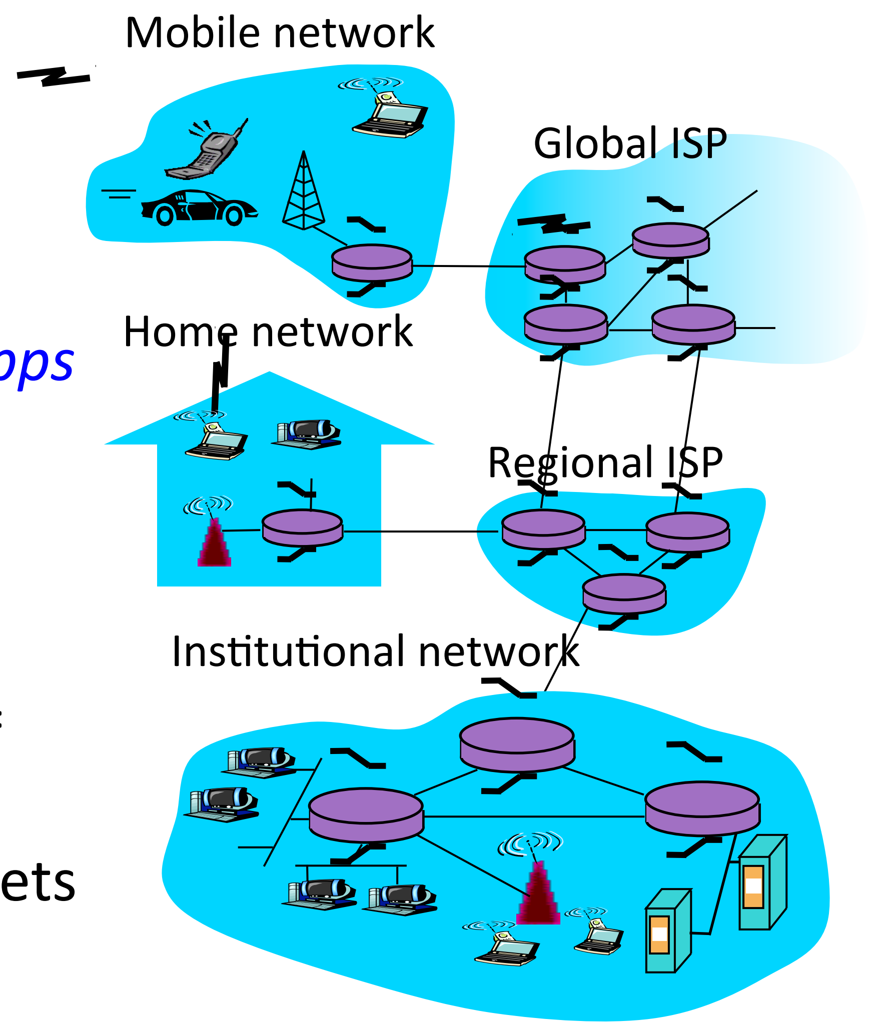
- Introduce the field and some of the jargon
- Give you some sense of why we think it is a good subfield
  - Beyond the guaranteed job security
- How we do research (so that other people care about it)

Overview:

- What are current networks?
- What works well?
- What is the bleeding edge?
- Some GMU research efforts

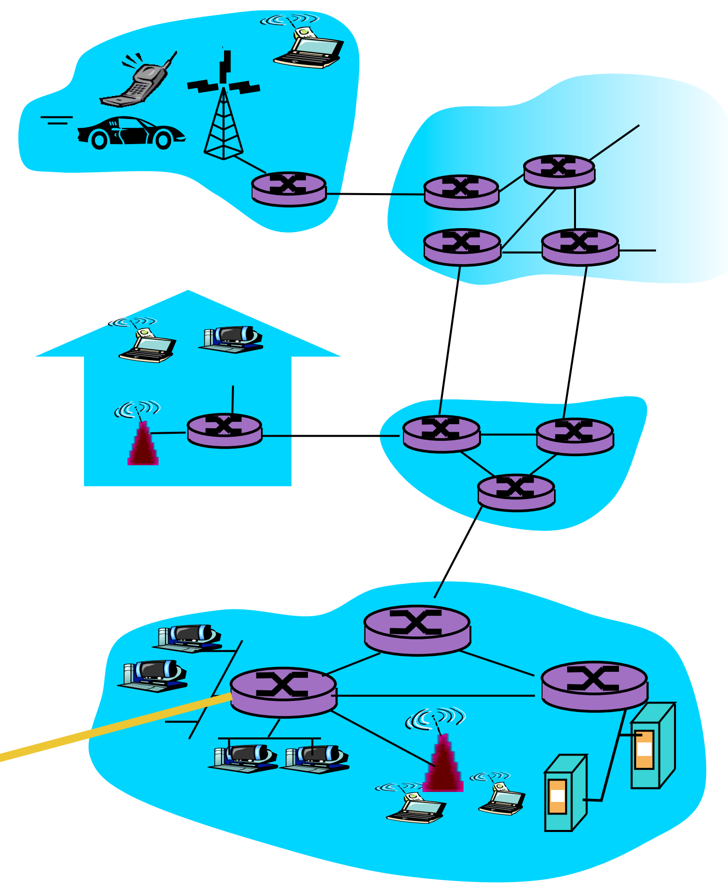
Internet

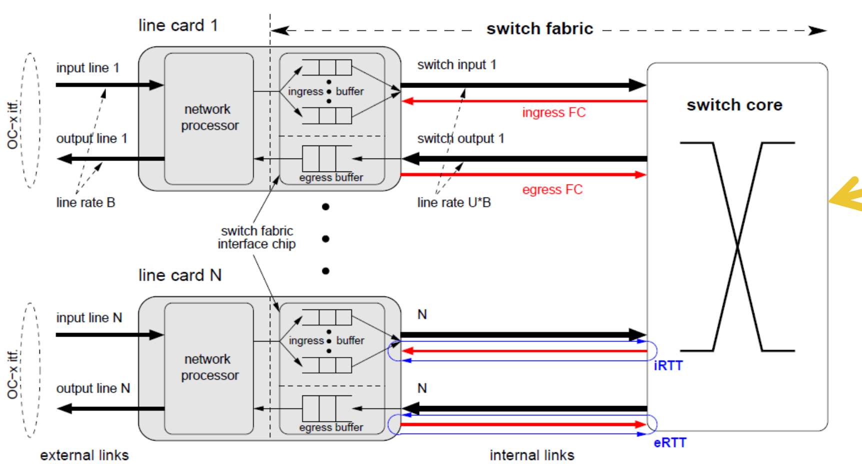
- 100's of millions of connected computing devices: *hosts = end systems*
  - running *network apps*
- *Communication links*
  - Fiber, copper, radio, satellite
  - Transmission rate = *bandwidth*
- *Routers:* forward packets (chunks of data)



A closer look at network structure:

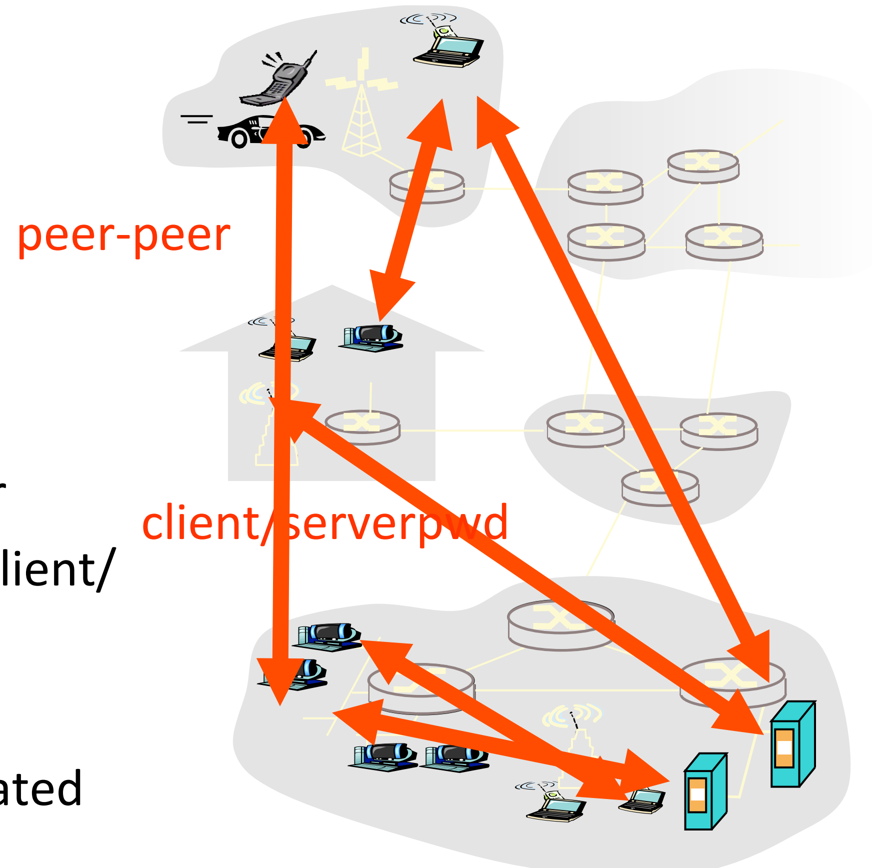
- **Access networks, physical media:** wired, wireless communication links
- **Network core:**
  - Interconnected routers
  - Network of networks





Distributed Systems

- End systems (hosts)
  - Run application programs
  - The "edge of network"



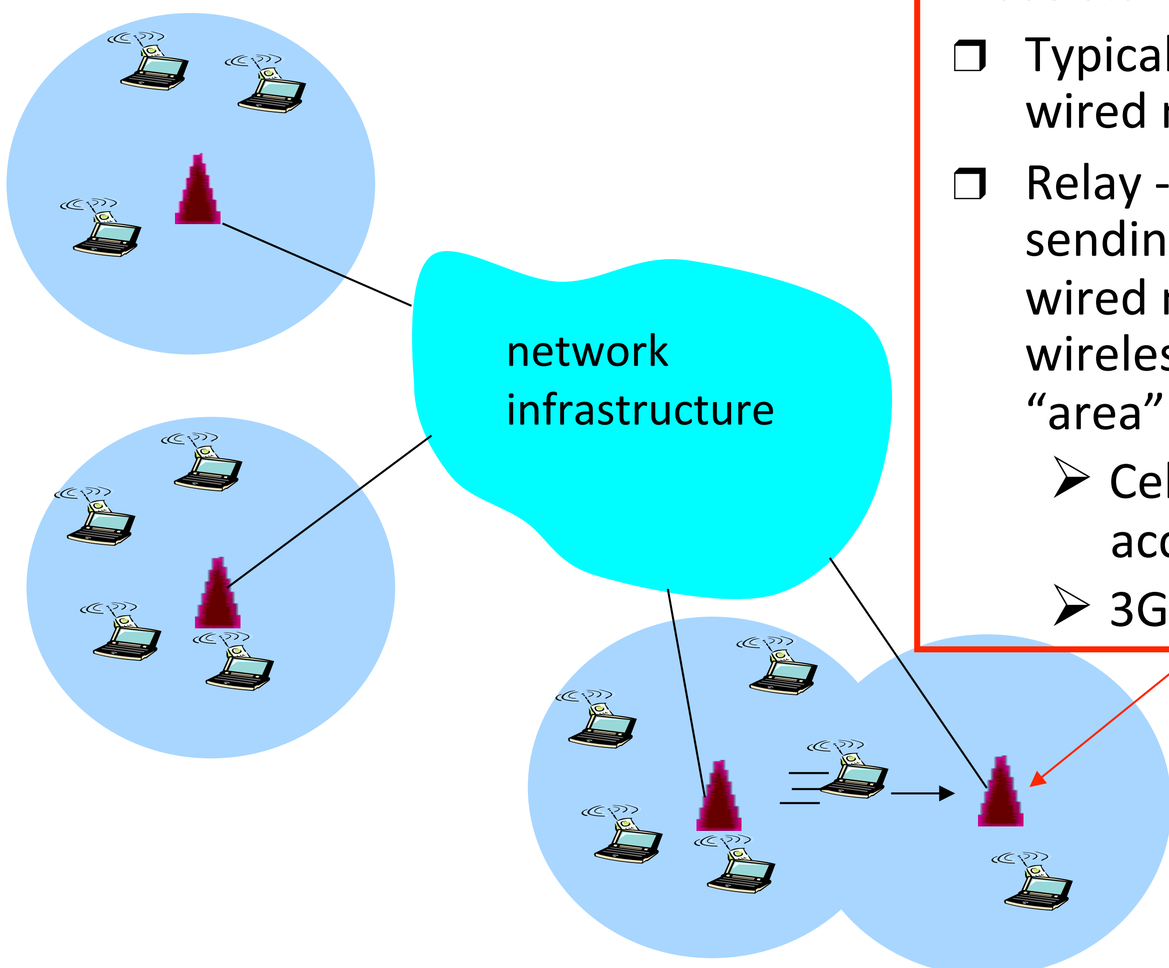
❒ Client/server model

- ➢ Client host requests, receives service from always-on server
- ➢ Web browser/server; email client/server

❒ Peer-peer model

- ➢ Minimal (or no) use of dedicated servers
- ➢ Skype, BitTorrent, etc.

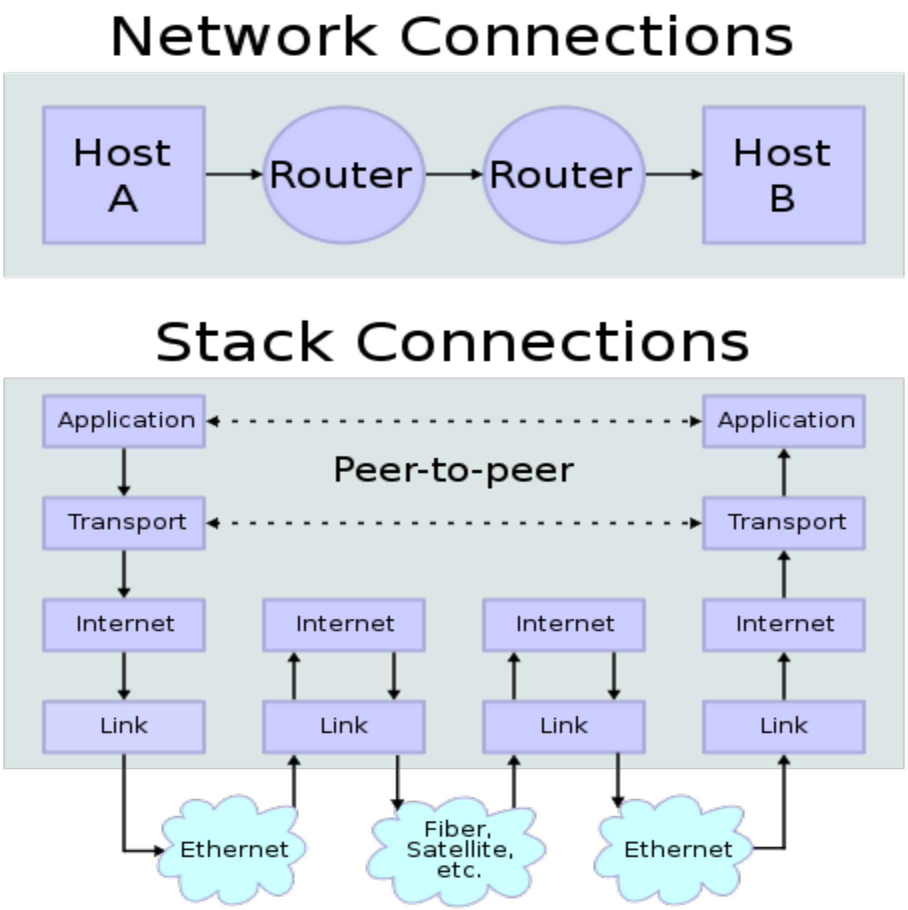
Wireless network

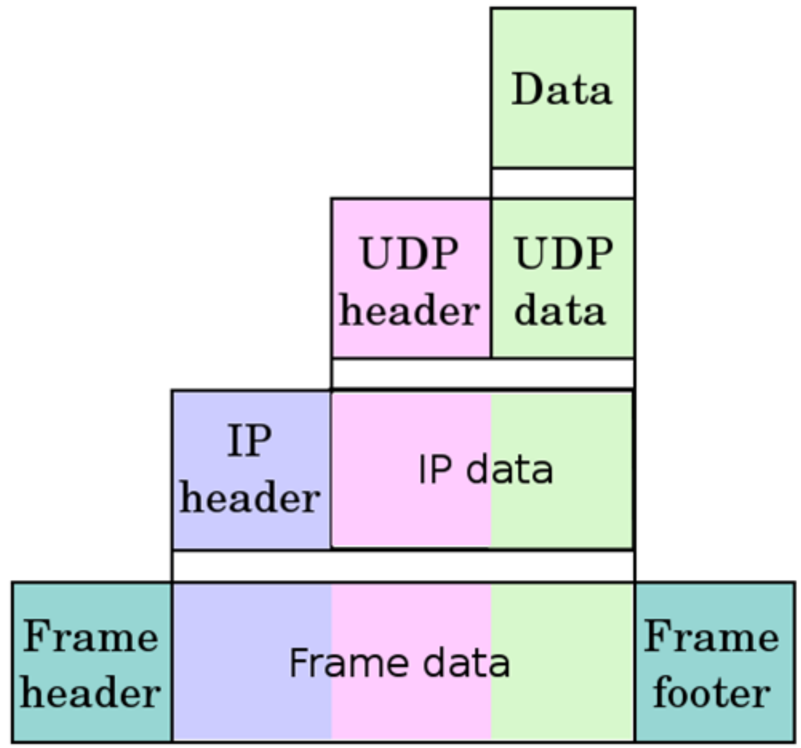


Base station

- Typically connected to wired network
- Relay - responsible for sending packets between wired network and wireless host(s) in its "area"
  - Cell towers, 802.11 access points
  - 3G, 4G

An Entire Networking Course in one slide



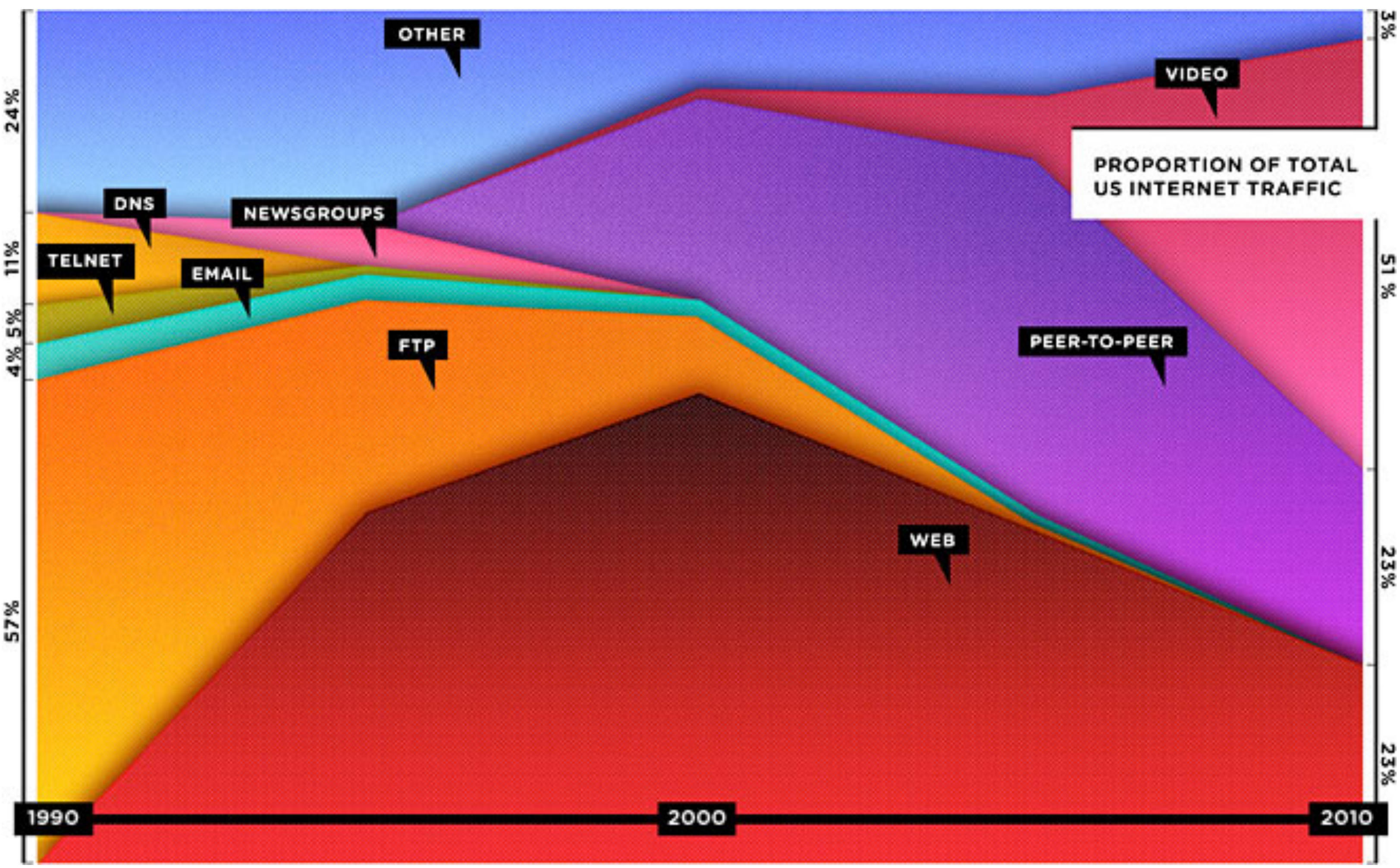


Copied from Wikimedia Commons

Current trends

What can glue together everything that can communicate??

Wired, August 2010: *The Web is dead(???)*



End of the PC

Vendors shipped 158.5 million smart phones in Q4 2011, up 57% on the 101.2 million units shipped in Q4 2010. This bumper quarter took total global shipments for the whole of 2011 to 487.7 million units, up 63% on the 299.7 million smart phones shipped throughout 2010. By comparison, the global client PC market grew 15% in 2011 to 414.6 million units, with 274% growth in pad shipments. Pads accounted for 15% of all client PC shipments in 2011.

Worldwide smart phone and client PC shipments

Shipments and growth rates by category, Q4 2011 and full year 2011

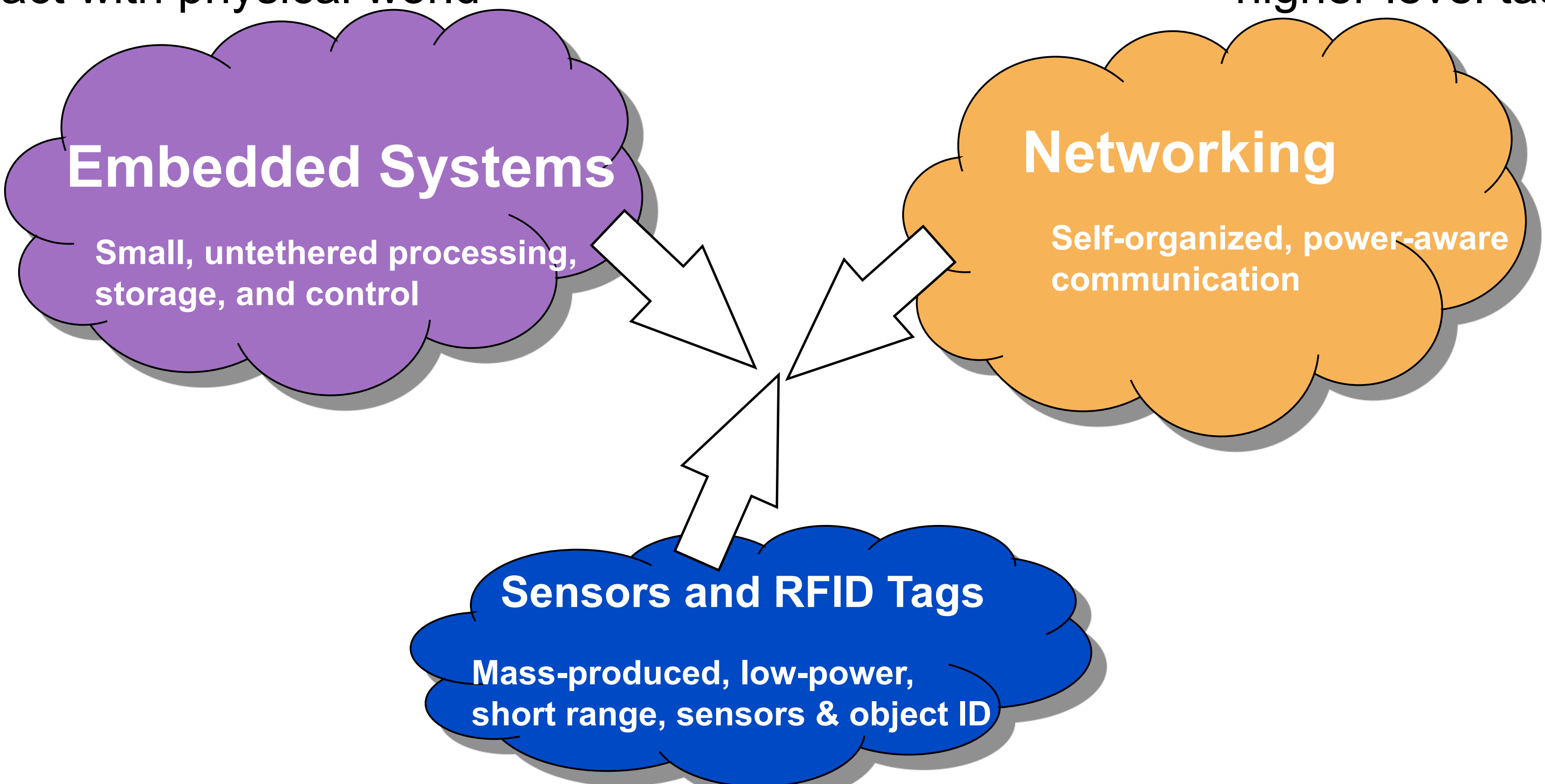
Category	Q4 2011 shipments (millions)	Growth Q4'11/Q4'10	Full year 2011 shipments (millions)	Growth 2011/2010
Smart phones	158.5	56.6%	487.7	62.7%
Total client PCs	120.2	16.3%	414.6	14.8%
- Pads	26.5	186.2%	63.2	274.2%
- Netbooks	6.7	-32.4%	29.4	-25.3%
- Notebooks	57.9	7.3%	209.6	7.5%
- Desktops	29.1	-3.6%	112.4	2.3%

Source: Canalys estimates © Canalys 2012

Internet of Smart Objects and the Internet of Everything

Many devices monitor and interact with physical world

Coordinate and perform higher-level tasks

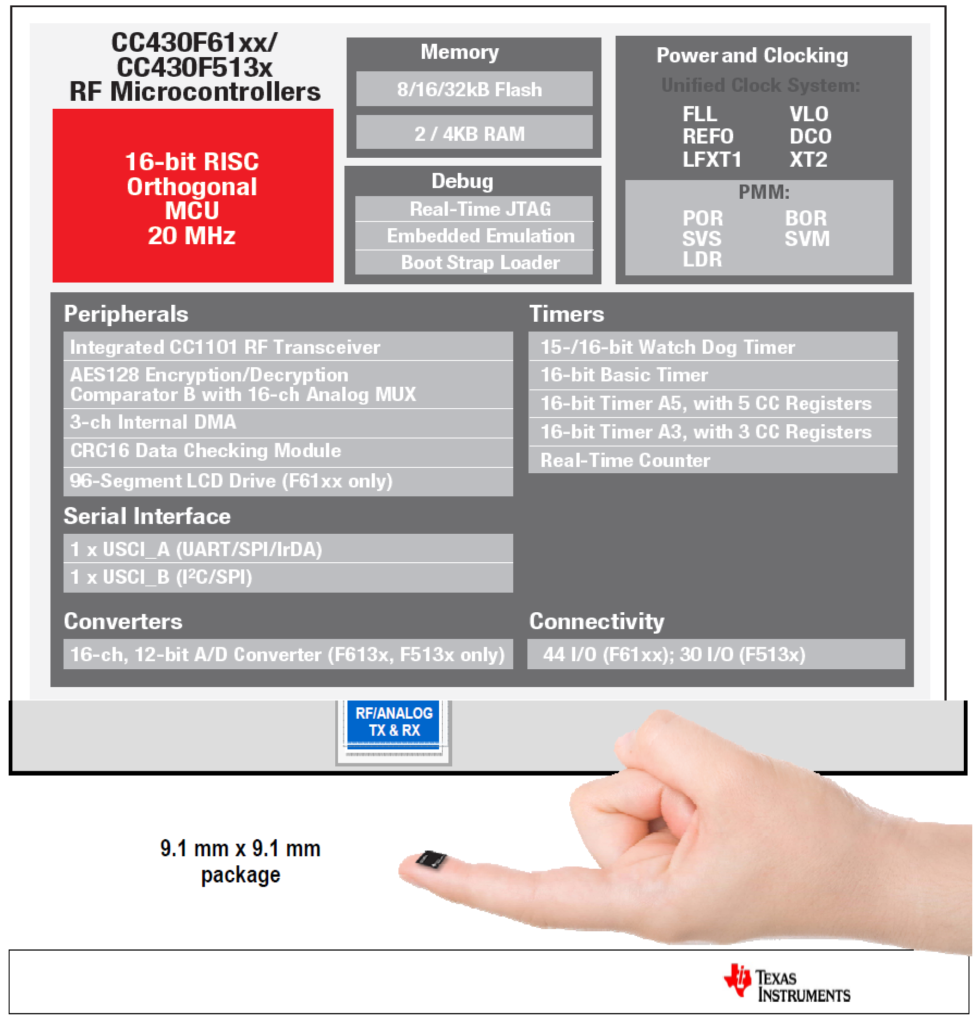


Exploit spatially and temporally dense coupling to physical world

Some Definitions

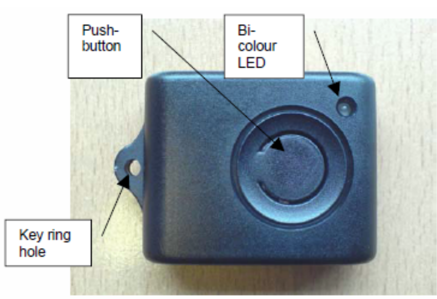
Wireless Sensor Networks

- 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

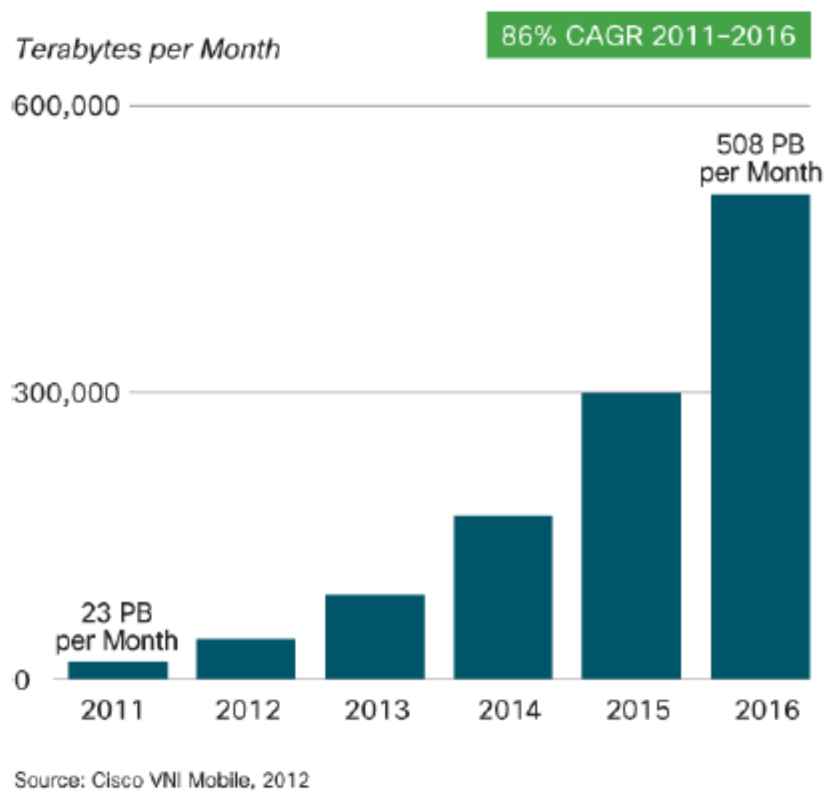


KSW Technic *VarioSense* Hybrid Power Tag

–*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)

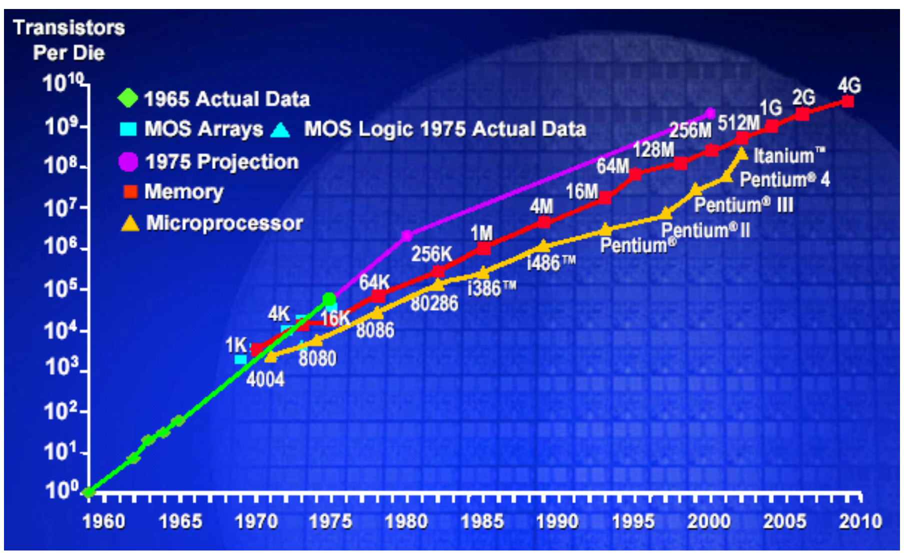
Machine-to-Machine Traffic Increase 22-Fold Between 2011 and 2016

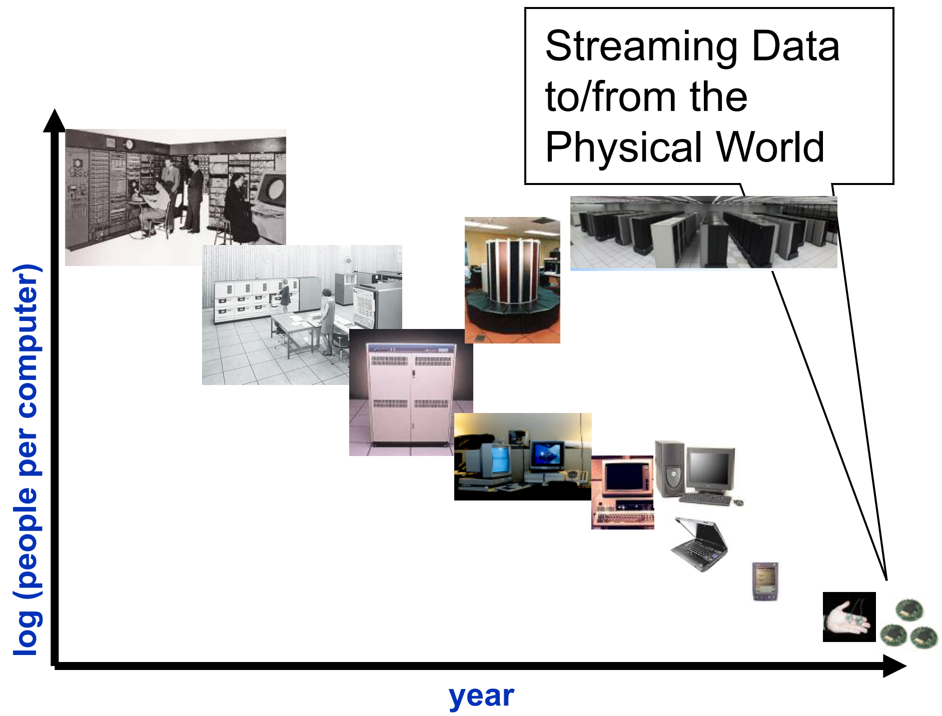


What's enabling this growth?

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

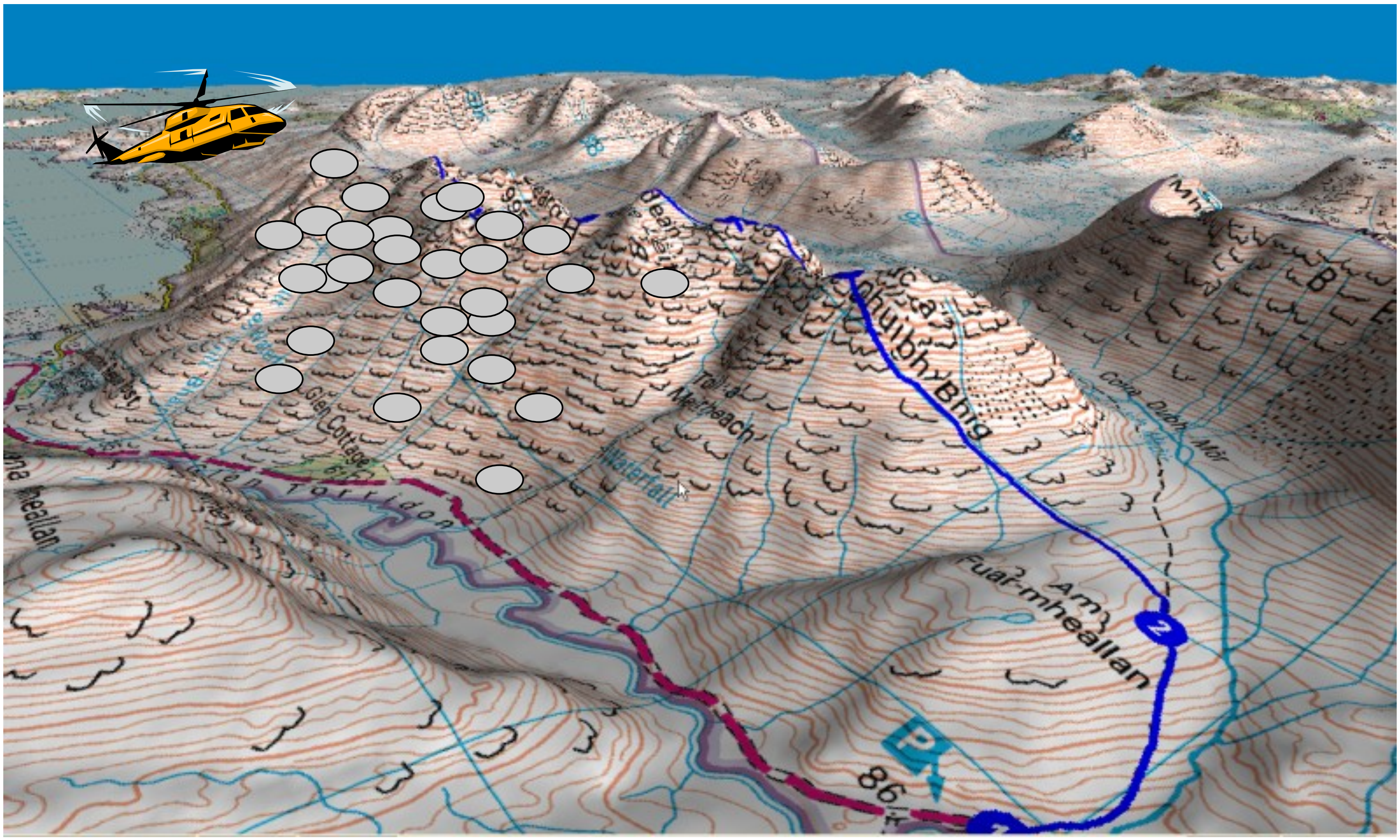
Transistors



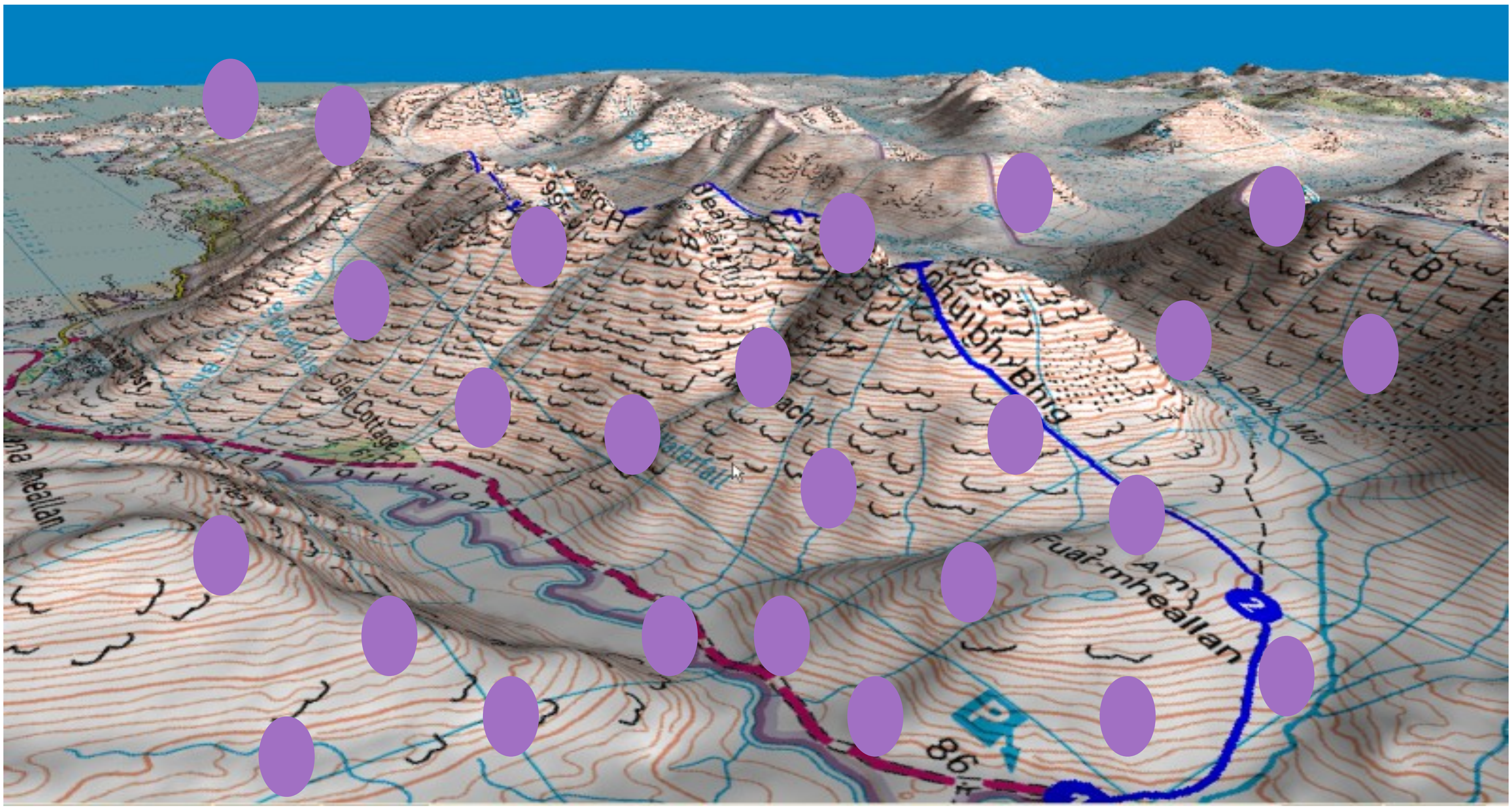


Research challenges, or how they work

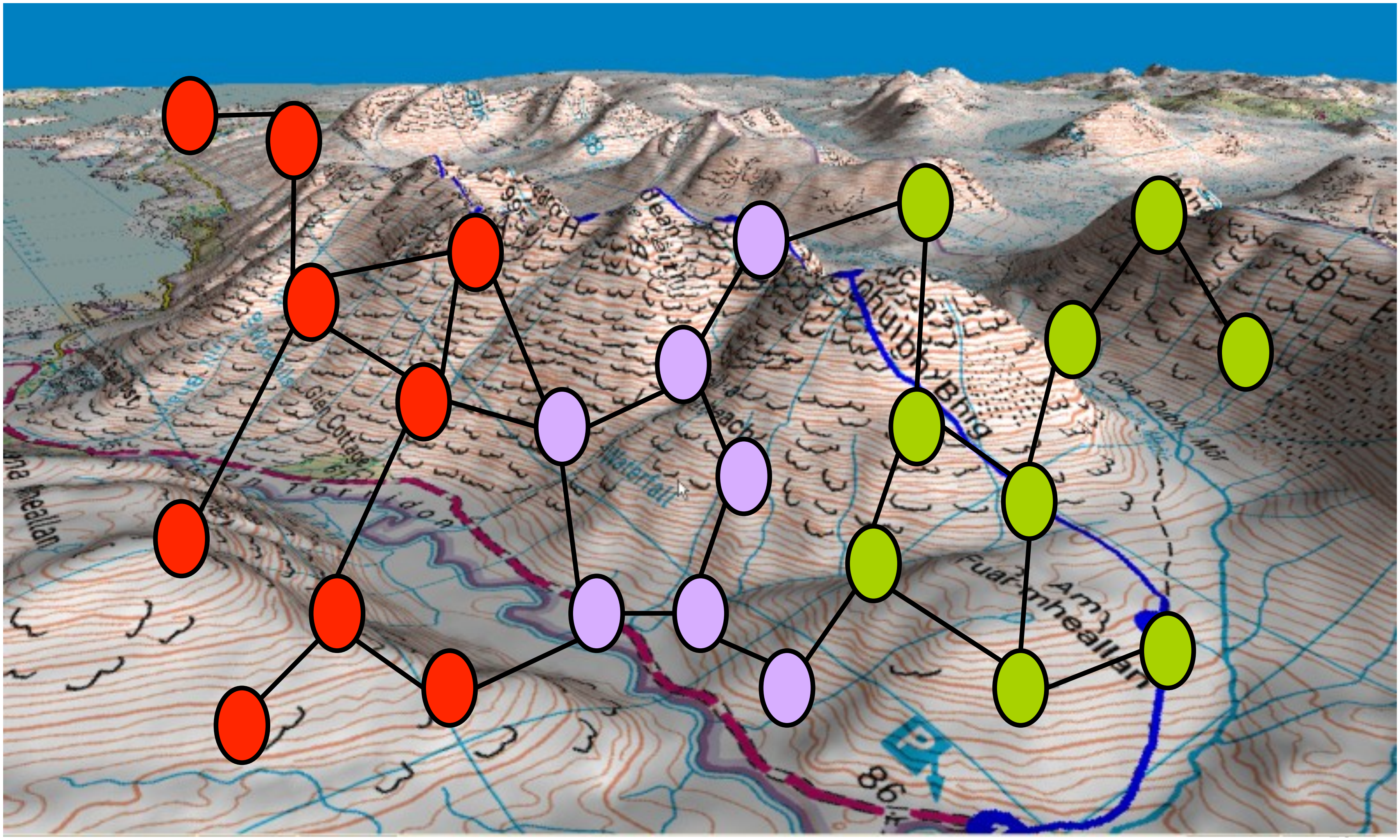
Sensor network lifetime -- Deploy



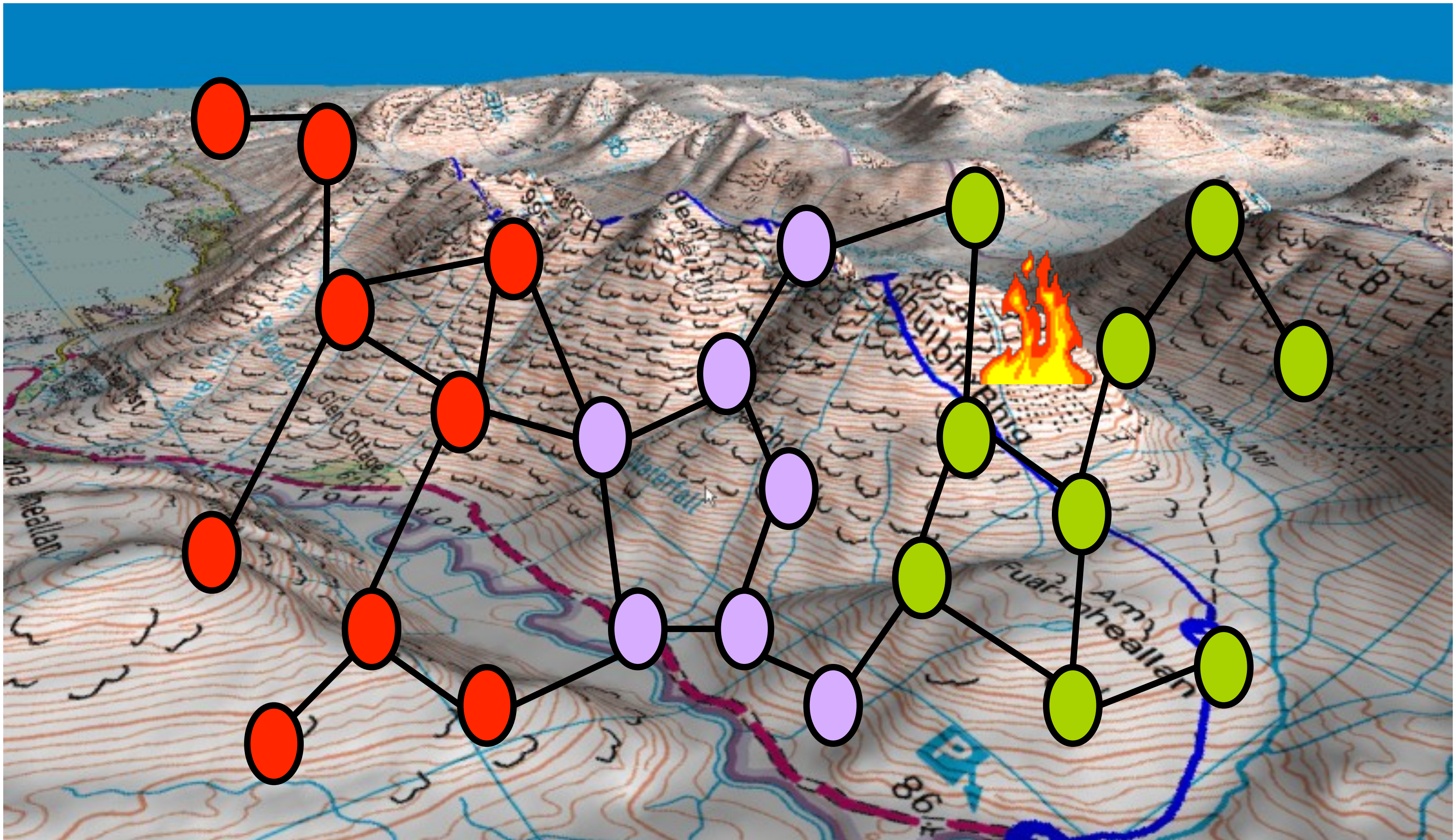
Wakeup and Diagnosis
What am I supposed to do?



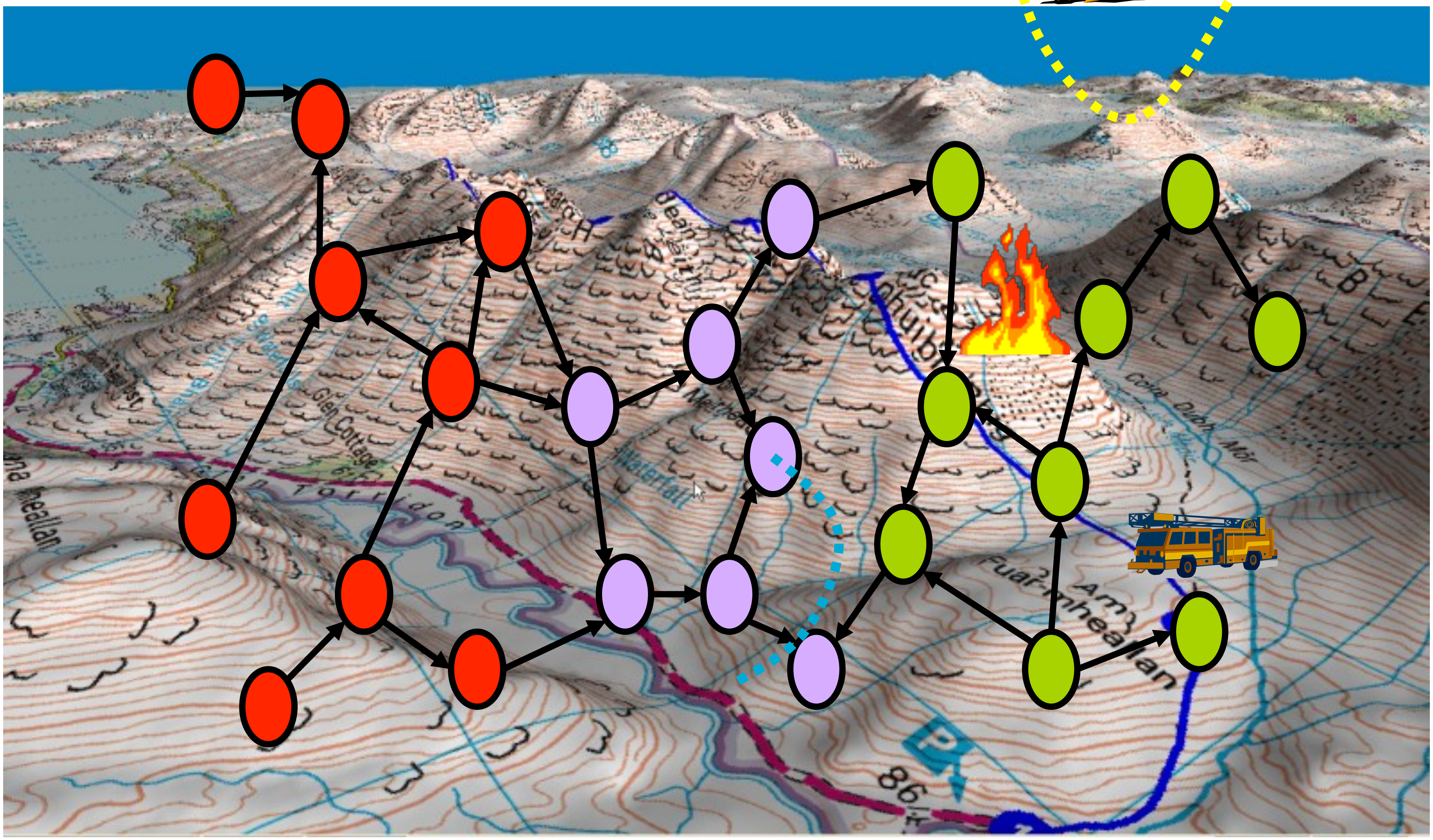
Organize into clusters – who can I talk to?



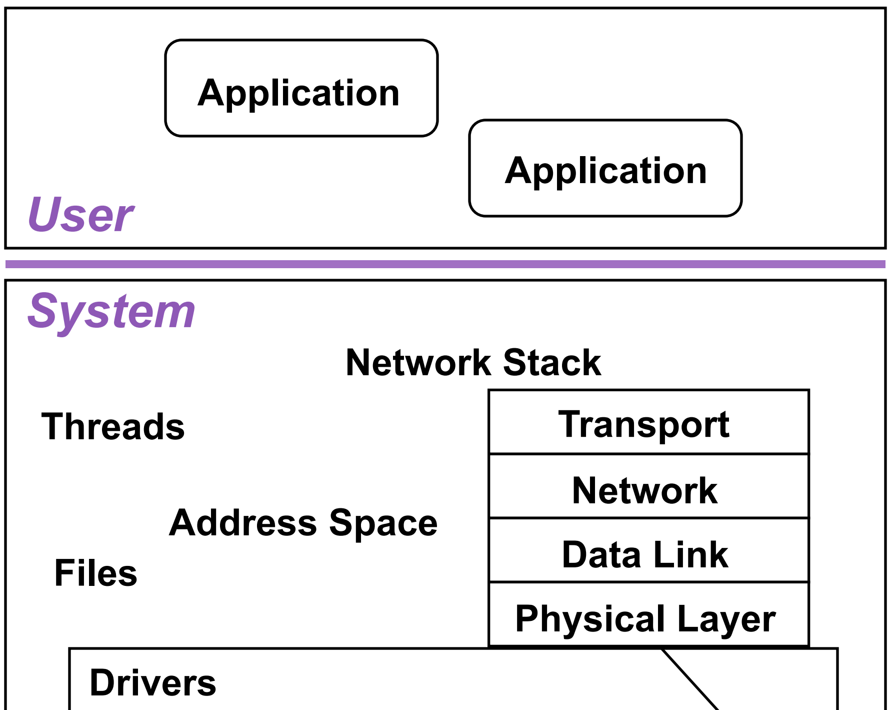
Detect Events –
Look for activity



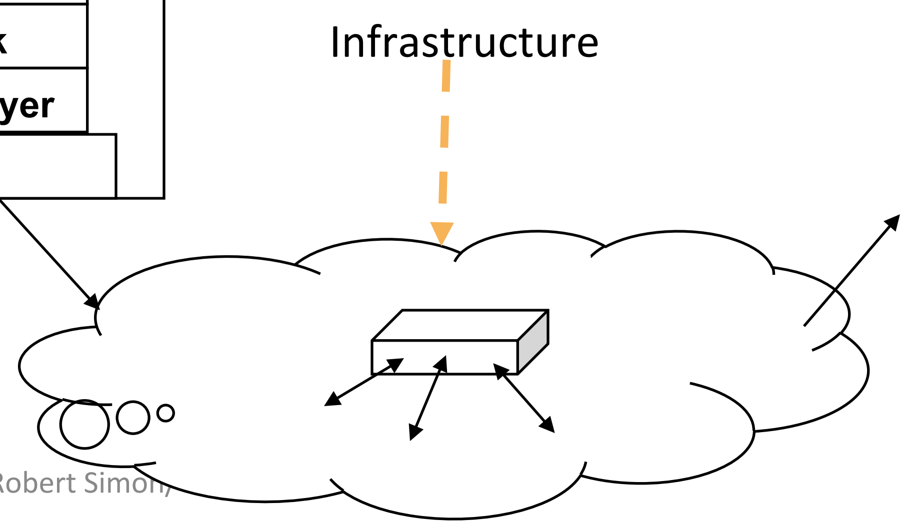
Route data --
Talk to nodes I cannot directly
communicate with



Traditional Wireless Systems (Your cellphone, Wi-Fi, etc).



- Well established layers of abstractions
- <u>Strict boundaries</u>
- Ample resources



WSNs: IS ANYTHING DIFFERENT HERE??

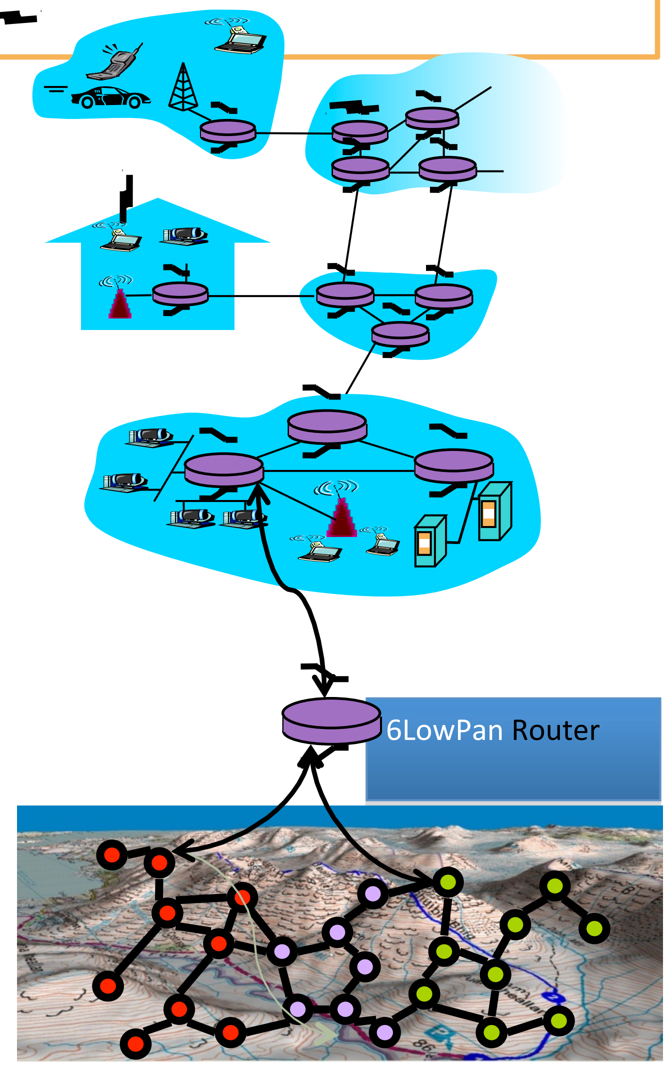
What are the challenges for embedded and sensor networks?

- Cannot adopt existing wireless distributed system technology
  - Must be able to automatically self-configure
  - Power constraints
  - May require energy harvesting
  - Storage constraints
  - Resource discovery and management complicated
  - Security constraints
  - AND: We want to run IP over everything!
- *The above are the current research challenges system designers face*

DEMO

Some GMU Embedded Systems Work

- Network and source coding
  - *Not writing code but using correlated data for compression and error correction*
- Routing and IPv6 over WSN networks
- Energy harvesting for multimedia WSNs (Joint work with Prof. Hakan Aydin)



RESEARCH Problem --Utility Maximization for Sensor Networks

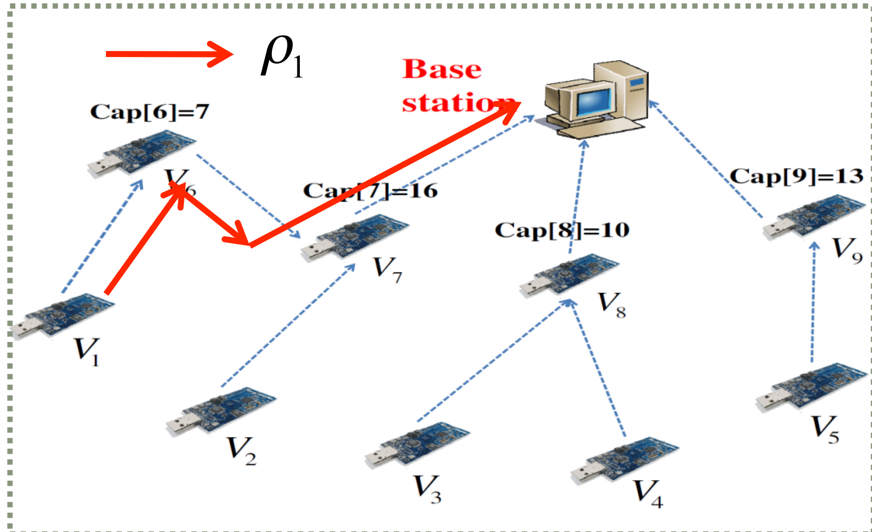
- Maximizing end-user perceived ***utility*** is of paramount importance to next-generation Wireless Sensor Networks (WSNs) applications.
- Utility often depends on application's sensing resolution (rate).
- Utility maximization is constrained by the limited battery capacity of sensor nodes.

high sensing rate	→	**high application utility**
↓		
high energy consumption	→	**short lifetime of sensor nodes**

A conflicting design goal: *Utility Maximization* or *Lifetime Maximization*?

Network Model

- A sensor network
  - consists of N sensor nodes.
  - is organized into a **data collection tree**, rooted at a base station (***BS***).



- Each sensor node is connected to BS by a single routing path ρ_i.

- Periodic data sensing and reporting at rate r_i
  r_i is the internal rate of nodes.

- Packet relaying for descendent nodes at external rate r_j.

- The total external rate at V_i :
  $\sum_{j:V_i \in \rho_j} r_j$.

- The total rate at V_i :
  $r_i + \sum_{j:V_i \in \rho_j} r_j$.

An optimal algorithm

- Problem conversion:

$$
\begin{aligned}
Max \quad & U^{tot} \\
s.t. \quad & \forall V_i, \\
& E_i^c \leq B_i \\
& r_i \geq r^{min} \\
& r_i + \sum_{j:V_i \in \rho_j} r_j \leq R_i^{cap}
\end{aligned}
$$

$$E_i^c = e^{tx} \cdot (r_i + \sum_{j:V_i \in \rho_j} r_j) \cdot S + E^{rx} \leq B_i$$

constant

$$r_i + \sum_{j:V_i \in \rho_j} r_j \leq \frac{B_i - E^{rx}}{e^{tx} \cdot S}$$

$$\forall V_i, r_i + \sum_{j:V_i \in \rho_j} r_j \leq CAPACITY_i$$

$$CAPACITY_i = Min \left\{ R_i^{cap}, \frac{B_i - E^{rx}}{e^{tx} \cdot S} \right\}$$

Forwarding capacity

Energy capacity

A simplified version with fewer constraints

$$
\begin{aligned}
Max \quad & U^{tot} = \sum_{i=1}^{N} U(r_i) \\
s.t. \quad & \forall V_i, r_i \geq r^{min} \\
& \forall V_i, r_i + \sum_{j:V_i \in \rho_j} r_j \leq CAPACITY_i
\end{aligned}
$$

Observations

- This work involves security protocols, electrical engineering, algorithms, cryptography, networks, embedded programming, etc.
- Many interesting overlaps among different research approaches
- Much GMU Graduate/Undergraduate involvement in these areas