Internet of Things
Unit 2

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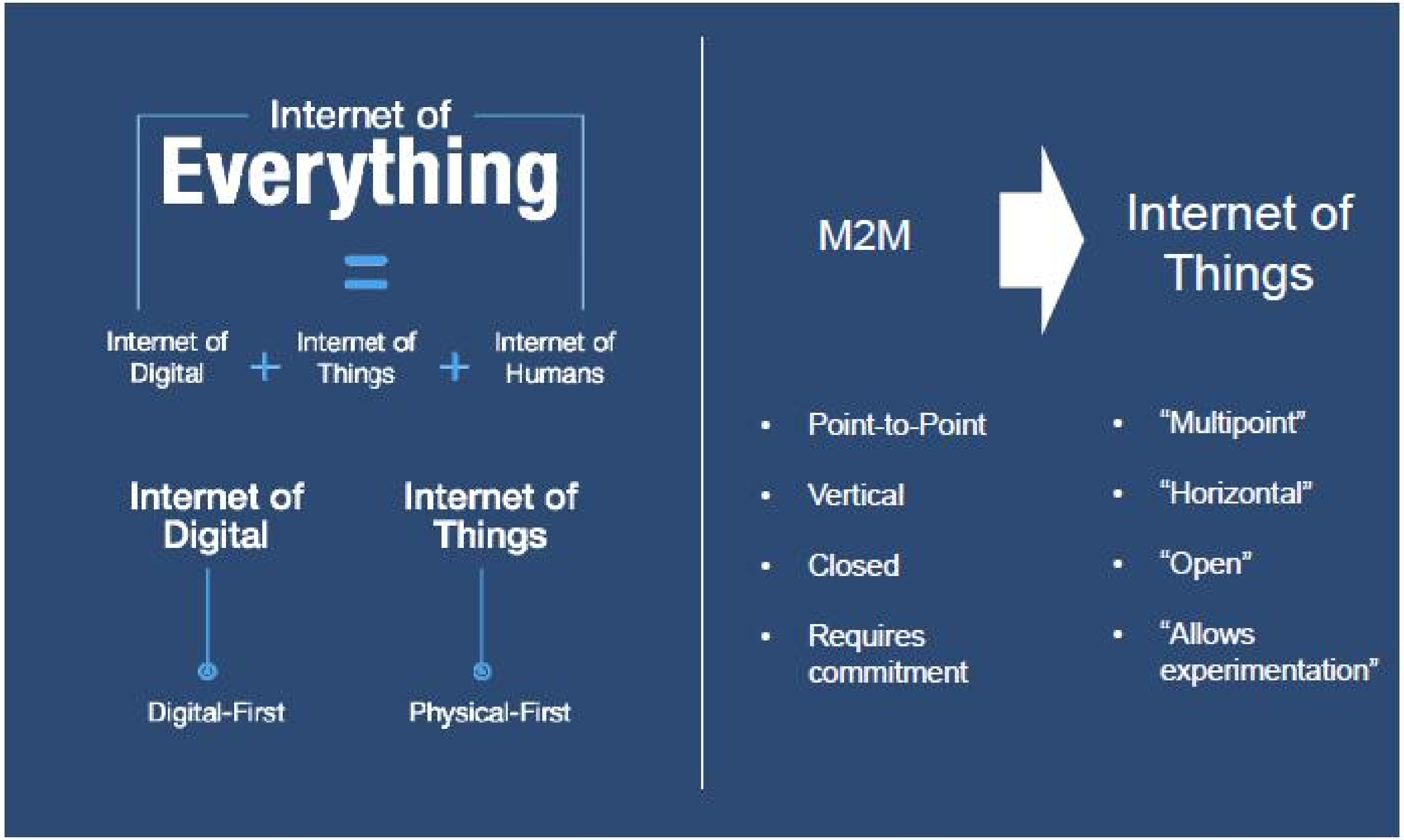
Introduction

- Machine-to-machine, or M2M, is a broad label that can be used to describe any technology that enables networked devices to exchange information and perform actions without the manual assistance of humans.
- M2M technology was first adopted in manufacturing and industrial settings, and later found applications in healthcare, business, insurance and more. It is also the foundation for the internet of things.
- **M2M** and **IoT** both refer to devices communicating with each other.
- M2M refers to isolated instances of device-to-device communication.
- IoT refers to a grander scale, synergizing vertical software

Difference

M2M	IoT
Machines	Sensors
Hardware-based	Software-based
Vertical applications	Horizontal applications
Deployed in a closed system	Connects to a larger network
Machines communicating with machines	Machines communicating with machines, humans with machines, machines with humans
Uses non-IP protocol	Uses IP protocols
Can use the cloud, but not required to	Uses the cloud
Machines use point-to-point communication, usually embedded in hardware	Devices use IP networks to communicate
Often one-way communication	Back and forth communication
Main purpose is to monitor and control	Multiple applications; multilevel communications
Operates via triggered responses based on an action	Can, but does not have to, operate on triggered responses
Limited integration options, devices must have complementary communication standards	Unlimited integration options, but requires software that manages communications/protocols
Structured data	Structured and unstructured data


Internet of
Everything
=
Internet of Digital
+
Internet of Things
+
Internet of Humans
Internet of Digital
Digital-First
Internet of Things
Physical-First
M2M
Internet of Things
Point-to-Point
Vertical
Closed
Requires commitment
“Multipoint”
“Horizontal”
“Open”
“Allows experimentation”

How M2M Works?

- The main purpose of machine-to-machine technology is to tap into sensor data and transmit it to a network.
- M2M systems often use public networks and access methods -- for example, cellular or Ethernet -- to make it more cost-effective.
- Energy efficiency and wireless connectivity are the key for M2M / IoT.
- M2M Communication is a subset of IoT.
- IoT comprises M2M and H2M (Human to Machine) communication.
- In practice the IoT will consist of hybrid infrastructure of non IP and IP connected devices through IP connected

- One of the most well-known types of machine-to-machine communication is telemetry, which has been used since the early part of the last century to transmit operational data.
- Pioneers in telemetrics first used telephone lines, and later, radio waves, to transmit performance measurements gathered from monitoring instruments in remote locations.
- The internet and improved standards for wireless technology have expanded the role of telemetry from pure science, engineering and manufacturing to everyday use in products such as heating units, electric meters and internet-connected devices, such as

Benefits of M2M

- Reduced costs by minimizing equipment maintenance and downtime.
- Boosted revenue by revealing new business opportunities for servicing products in the field.
- Improved customer service by proactively monitoring and servicing equipment before it fails or only when it is needed.

Network QoS Requirements

- M2M communication is different from the voice communication as size of data in M2M may vary from few bytes (meter reading) to several MBs (surveillance video in).
- M2M services requirement
  - **Timely transmission is of utmost important.**
  - **Communication network is required to be more reliable with low latency**

S. No.	Industry / Vertical	M2M applications
1.	Smart City	Intelligent transport System, Waste management, Smart Street Light system, Electric vehicle charging, Water management, Smart Parking, Intelligent buildings, Safety & Surveillance,
2.	Automotive / Intelligent Transport System	Vehicle tracking, e-call, V2V and V2I applications, traffic control, Navigation, Infotainment, Fleet management, asset tracking, manufacturing and logistics
3.	Safety & Surveillance	Commercial and home security monitoring, Surveillance applications, Video analytics and sending alerts, Fire alarm, Police / medical alert
4.	Utilities / Energy	Smart metering, smart grid, Electric line monitoring, gas / oil / water pipeline monitoring.
5.	Health care	Remote monitoring of patient after surgery (e-health), remote diagnostics, medication reminders, Tele-medicine, wearable health devices
6.	Smart Homes	Video monitoring of home, Security & Alarm, Door control, HVAC control, Smart lighting for efficiency, Controlling appliances through Smart phones etc.
7.	Financial /Retail	Point of sale (POS), ATM, Kiosk, Vending machines, digital signage and handheld terminals.
8.	Water	Smart metering, Water leakage management

Applications

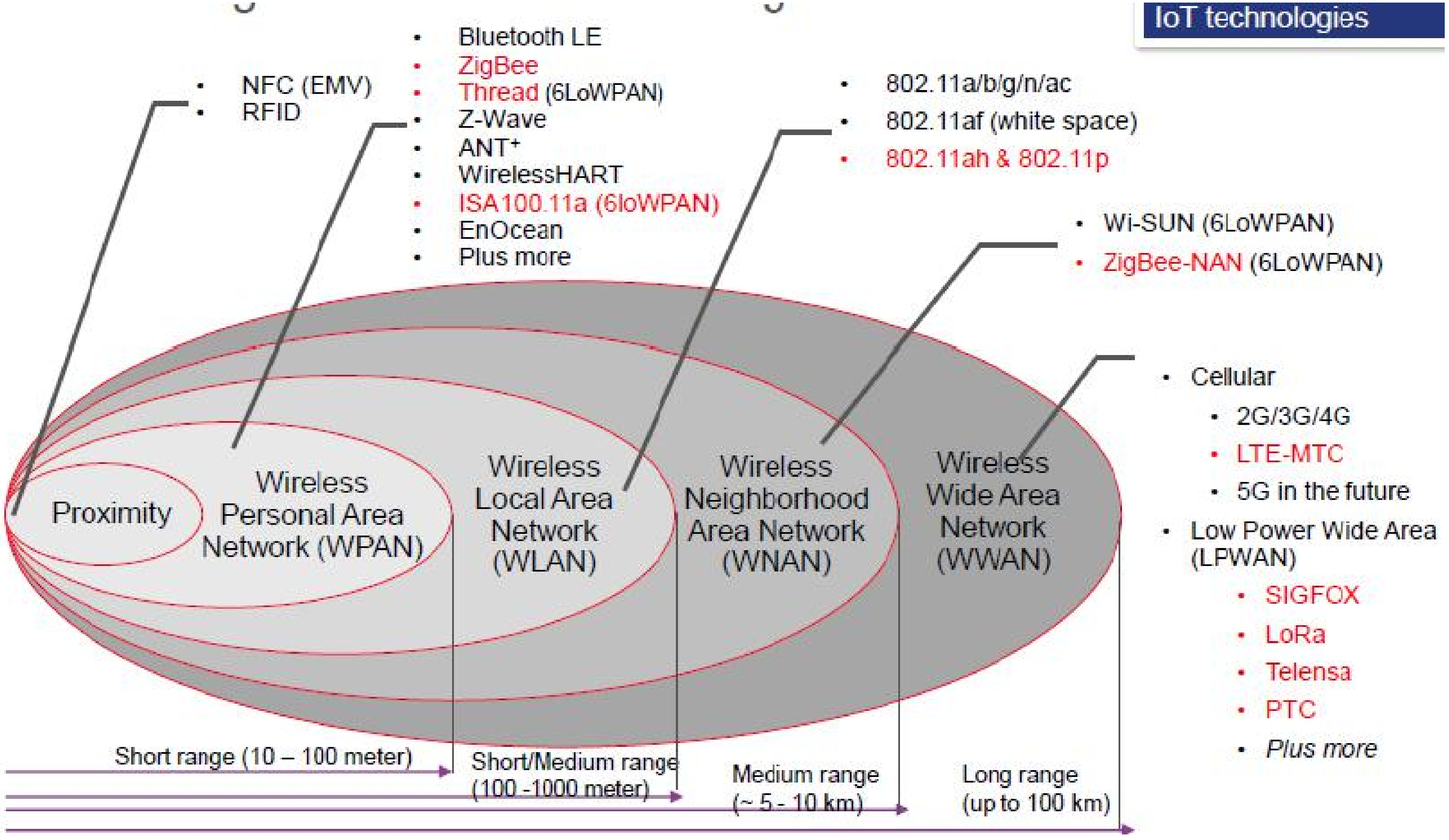
- Machine-to-machine communication is often used for remote monitoring.
- M2M devices can enable the real-time monitoring of patients' vital statistics, dispensing medicine when required, or tracking healthcare assets.
- M2M is also an important aspect of remote control, robotics, traffic control, security, logistics and fleet management, and automotive.

Enabling technologies for M2M

- Sensor networks, Radio frequency Identification (RFID) chips, GPS, *Location-Based Services* (LBS), nanotechnologies, cloud services, data analytics.
- **WLAN (IEEE 802.11), Bluetooth Low Energy (BLE), NFC,** DSRC for short range communication.
- Low Power RF for LAN / FAN such as 6LowPAN, Zigbee, Zwave, Wi-SUN etc
- Cellular 2G/ 3G/ LTE / Satellite for Long range communication depending upon the applications.
- Wire line BB / Lease line to connect infrastructure
- Power Line Communication Technologies: Narrowband PLC for LAN / FAN and Broadband PLC for WAN
- Low power RF for WAN: LoRa, Sigfox
- **Embedded SIM**
- **Static IP (IPv4 / IPv6)**
- **Smart Phone**
- **High speed internet on fixed line and mobile phones.**

Backbone network

- Smooth & high speed WiFi coverage, WiFi offloading with the TSPs.
- Control plane at the center whereas data may be in distributed servers.
- Data centers in the cloud for storing large amount of data from the devices.
- Big data analytics to create intelligence.
- Use of intelligence for different activities.
- Open APIs
- ICT Infrastructure
- **RFID** based system.

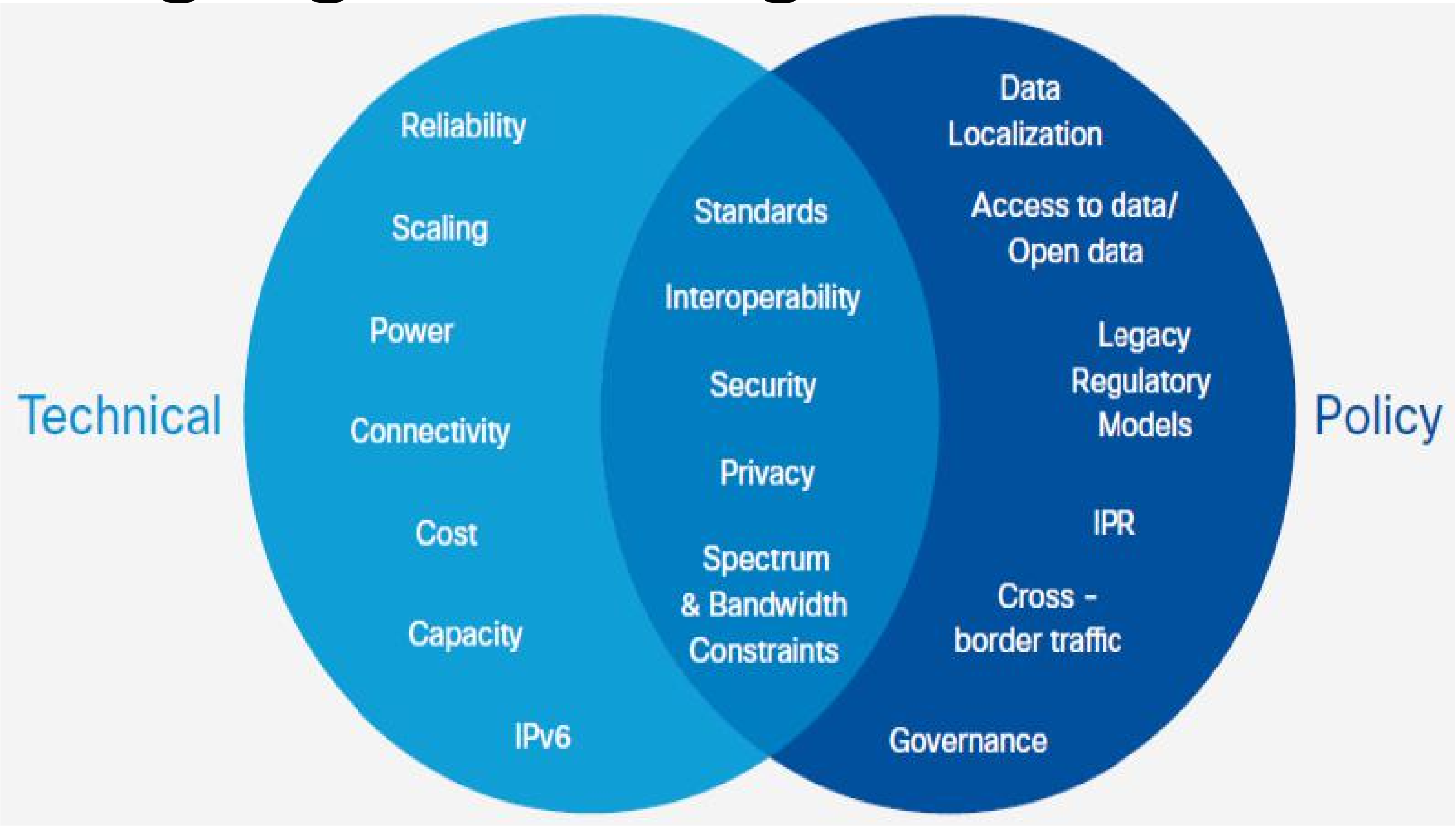


IoT technologies
NFC (EMV)
RFID
Bluetooth LE
ZigBee
Thread (6LoWPAN)
Z-Wave
ANT+
WirelessHART
ISA100.11a (6loWPAN)
EnOcean
Plus more
802.11a/b/g/n/ac
802.11af (white space)
802.11ah & 802.11p
Wi-SUN (6LoWPAN)
ZigBee-NAN (6LoWPAN)
Cellular
2G/3G/4G
LTE-MTC
5G in the future
Low Power Wide Area (LPWAN)
SIGFOX
LoRa
Telensa
PTC
Plus more
Proximity
Wireless Personal Area Network (WPAN)
Wireless Local Area Network (WLAN)
Wireless Neighborhood Area Network (WNAN)
Wireless Wide Area Network (WWAN)
Short range (10 – 100 meter)
Short/Medium range (100 -1000 meter)
Medium range (~ 5 - 10 km)
Long range (up to 100 km)

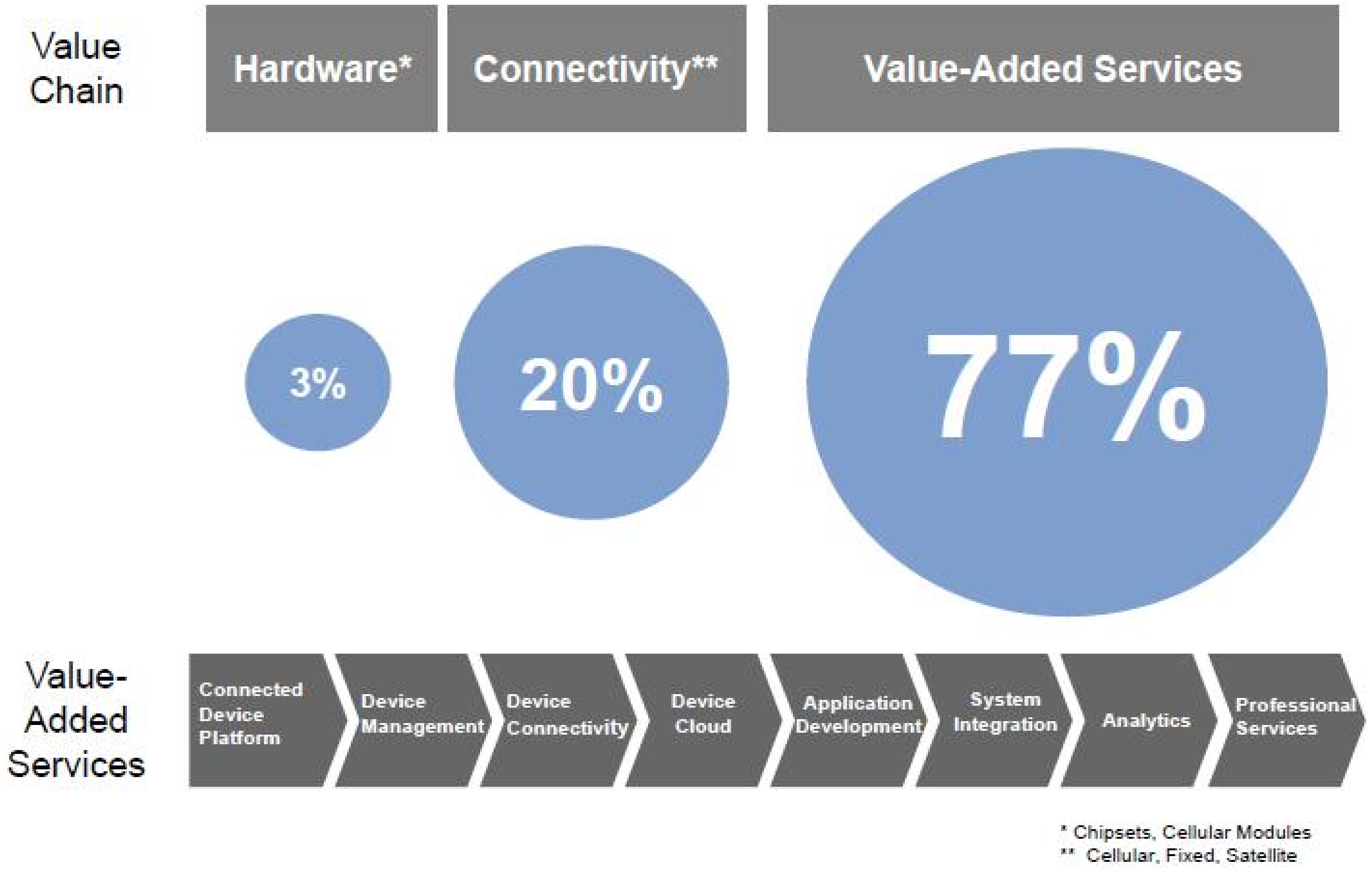
Challenges and need for standards

- Lack of standards and interoperable technologies
- Technologies for sustainability or low power consumption / long life batteries required for sensors.
- There should be interoperability at device, network and application levels.
- Slow deployment of IPv6
- Low cost devices (affordability)
- Data Security & Privacy
- Health care regulations

Emerging Challenges



M2M Value Chain



Wireless Sensor Network (WSN)

Wireless Sensors

Low-power microscopic sensors with wireless communication capability

- Miniaturization of computer hardware
  Intelligence
- Micro Electro-Mechanical Structures (MEMS)
  Sensing
- Low-cost CMOS-based RF Radios
  Wireless Communications

Wireless Sensor Networks(WSN)

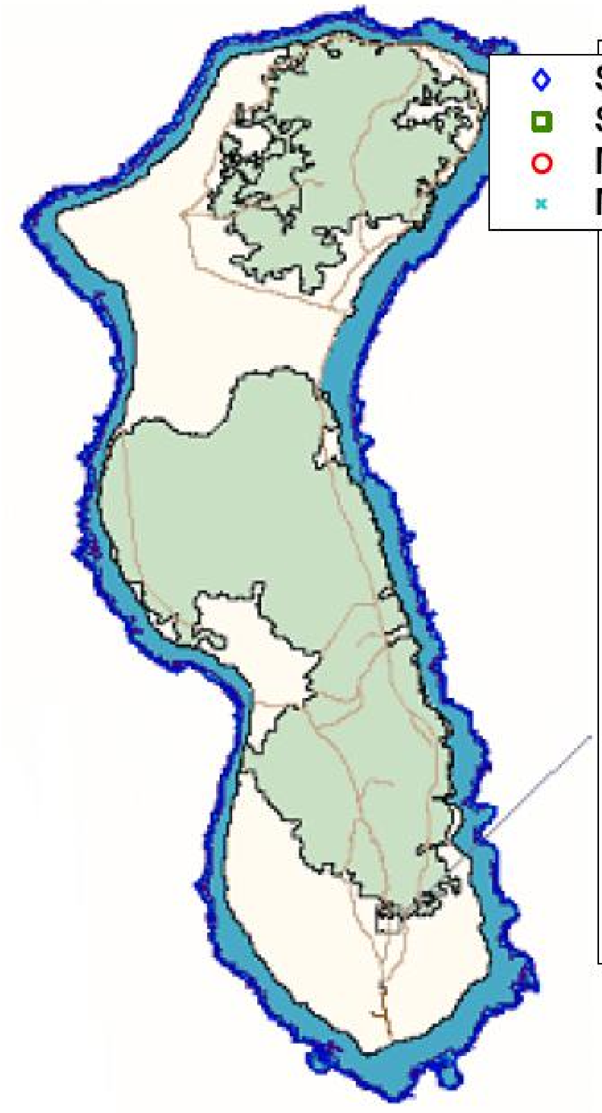
- Even though wireless sensors has limited resources in memory, computation power, bandwidth, and energy.
- With small physical size   Can be embedded in the physical environment.
- Support powerful service in aggregated form (interacting/collaborating among nodes)
- *Self-organizing multi-hop ad-doc networks*
- Pervasive computing/sensoring

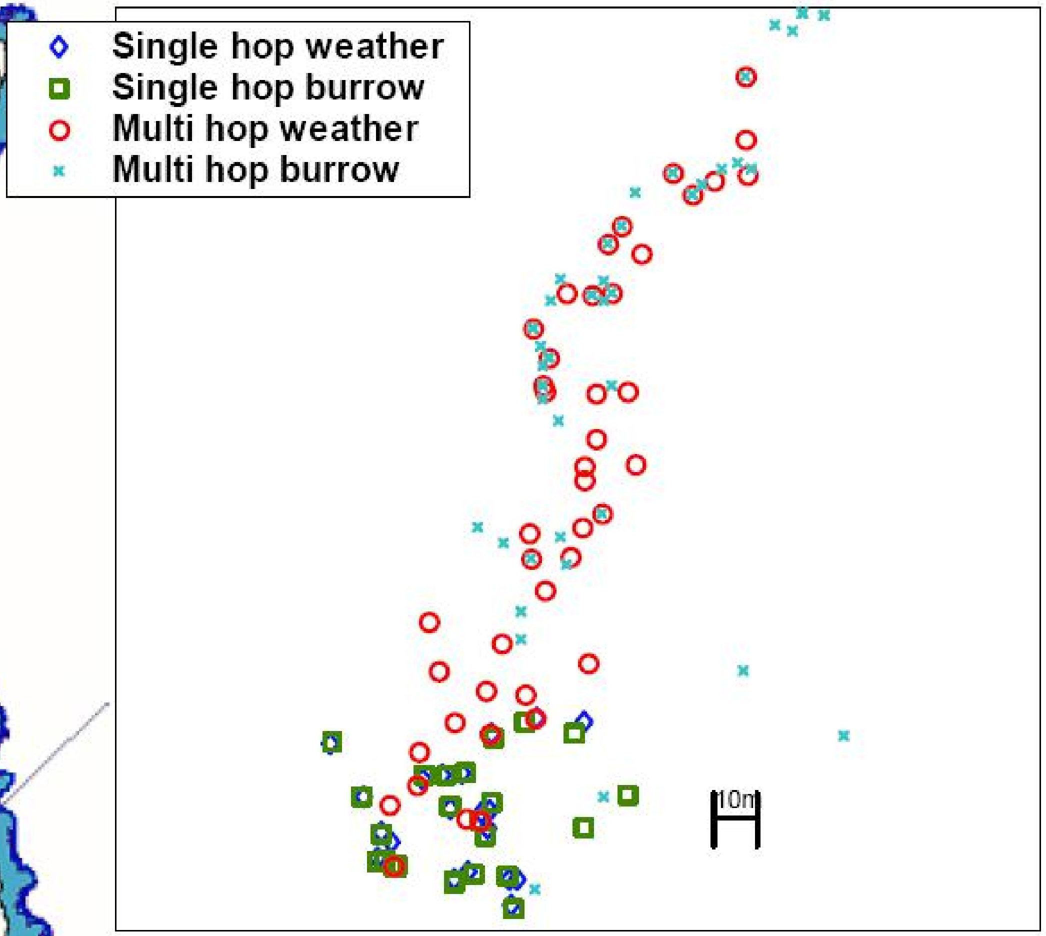
WSN Applications

- Wide area monitoring tools supporting Scientific Research
  - Wild life Habitat monitoring projects Great Duck Island (UCB), James Reserve (UCLA), ZebraNet (Princeton.
  - Building/Infrastructure structure study (Earthquake impact)
- Military Applications
  - Shooter Localization
  - Perimeter Defense (Oil pipeline protection)
  - Insurgent Activity Monitoring (MicroRadar)

- Commercial Applications
  - Light/temperature control
  - Precision agriculture (optimize watering schedule)
  - Asset management (tracking freight movement/storage)

Senor Network/Great Duck Island 2003

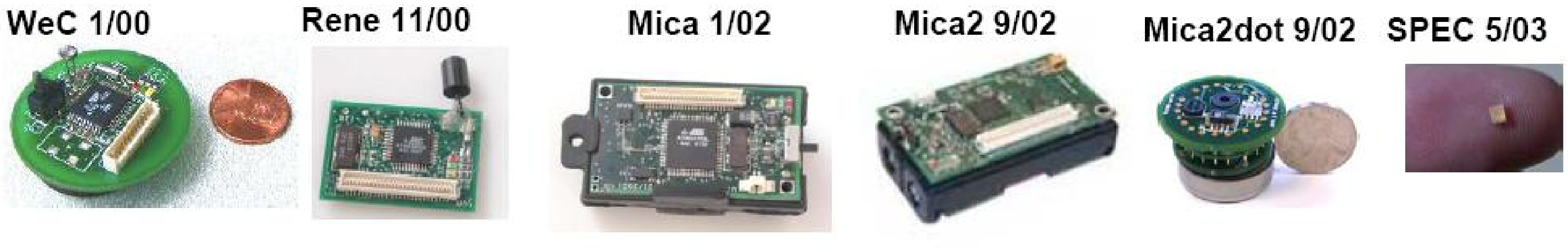




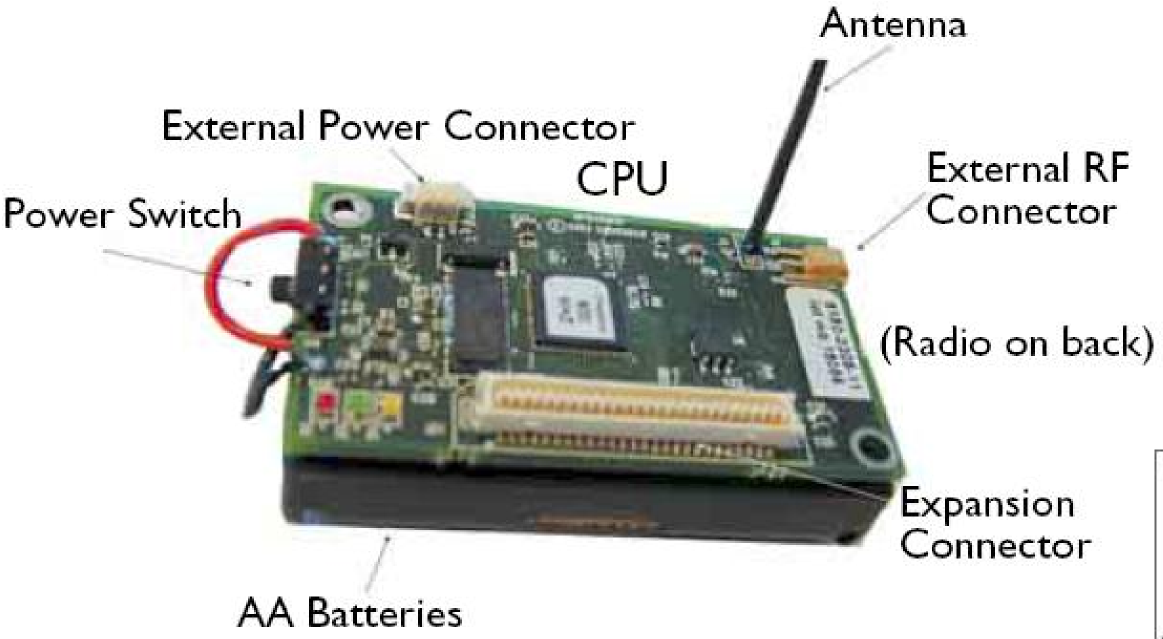
What is a mote?

Imote2 06 with enalab camera

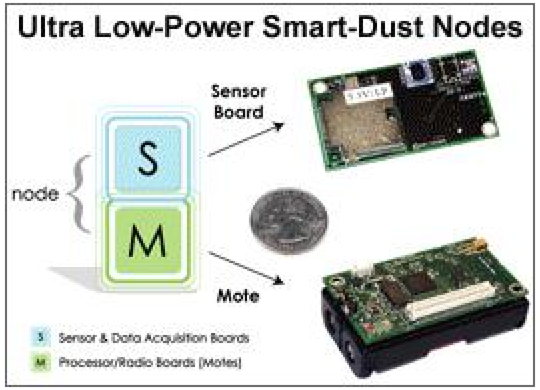
- **mote**
  something, especially a bit of dust, that is so small it is almost impossible to see



Mica2 Wireless Sensors
CACM June 2004 pp. 43.

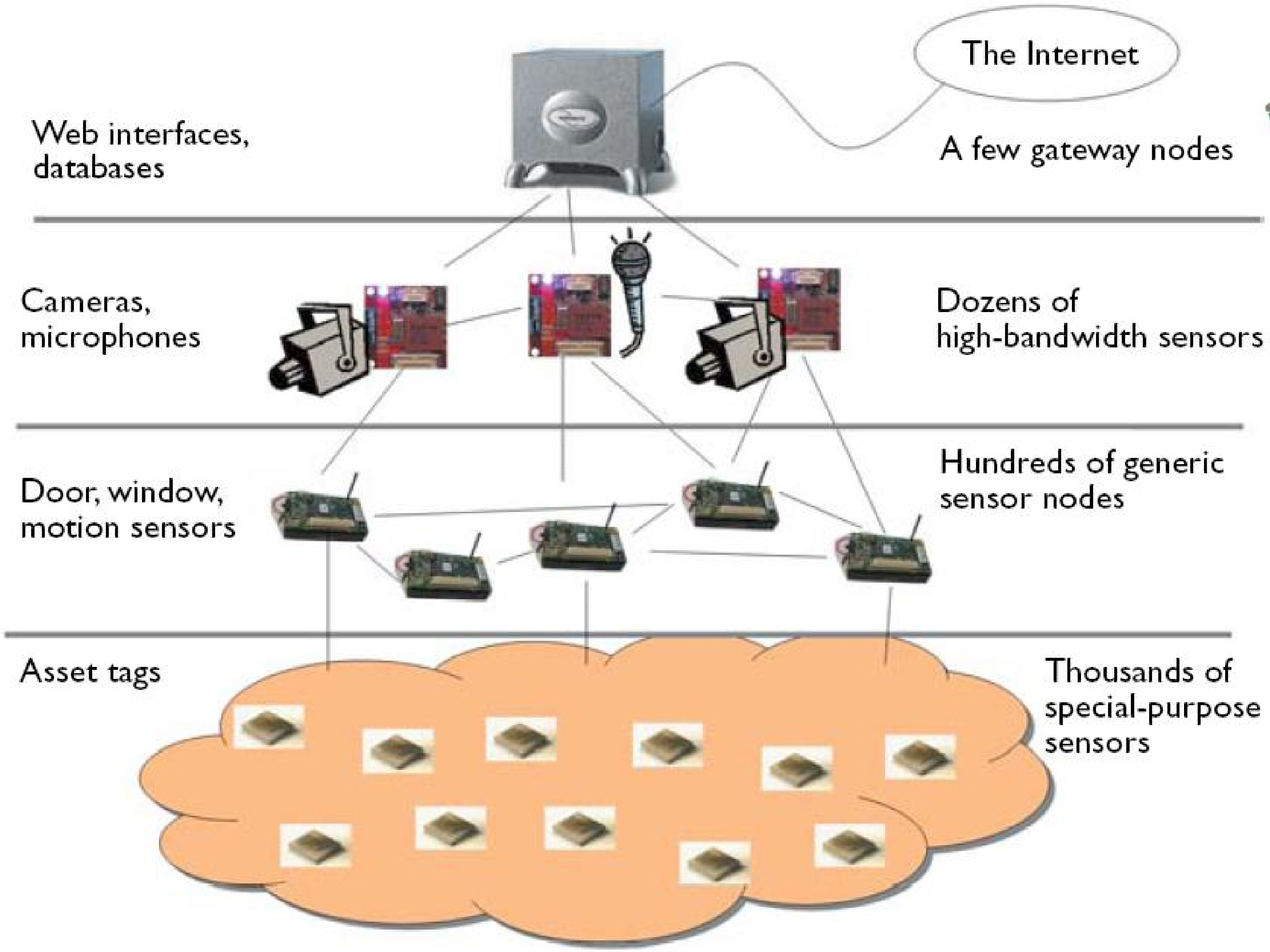


MTS310 Sensor Boards
- Acceleration,
- Magnetic,
- Light,
- Temperature,
- Acoustic,
- Sounder



New MicaZ follows IEEE 802.15.4 Zigbee standard with direct sequence sprad spectrum radio and 256kbps data rate

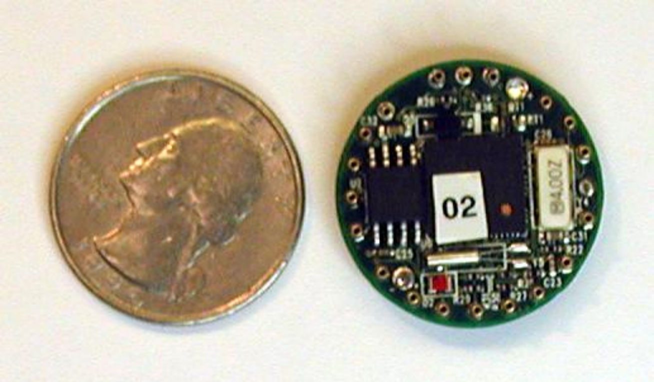
Wireless Sensor Network



Stargate

- 802.11a/b
- Ethernet
- Mica2
- PCMCIA
- Compactflash
- USB
- JTAG
- RS232

Motes and TinyOS



- **Motes** (Mica2, Mica2dot, MicaZ)
  - Worked well with existing curriculum
    - ATMega128L microcontroller
    - 128KB program flash; 512KB measurement Flash; 4KB EEPROM
  - Standard platform with built-in radio chicon1000 (433MHz, 916MHz, 2.4GHz) 38.4kb; 256kbps for MicaZ IEEE 802.15.4. (1000ft, 500ft; 90/300ft) range
  - AA battery
  - Existing TinyOS code base
  - Convenient form factor for adding sensors
- **TinyOS**
  - Event-based style helped students understand:
    - Time constraints
    - Code structure (need to write short non-blocking routines)
  - Existing modular code base saved time
    - Made a more complex project possible
    - Provided a degree of abstraction

Comparison of Energy Sources

	Power (Energy) Density	Source of Estimates
Batteries (Zinc-Air)	1050 -1560 mWh/cm^3 (1.4 V)	Published data from manufacturers
Batteries(Lithium ion)	300 mWh/cm^3 (3 - 4 V)	Published data from manufacturers
Solar (Outdoors)	15 mW/cm^2 - direct sun 0.15mW/cm^2 - cloudy day.	Published data and testing.
Solar (Indoor)	.006 mW/cm^2 - my desk 0.57 mW/cm^2 - 12 in. under a 60W bulb	Testing
Vibrations	0.001 - 0.1 mW/cm^3	Simulations and Testing
Acoustic Noise	3E-6 mW/cm^2 at 75 Db sound level 9.6E-4 mW/cm^2 at 100 Db sound level	Direct Calculations from Acoustic Theory
Passive Human Powered	1.8 mW (Shoe inserts >> 1 cm^2)	Published Study.
Thermal Conversion	0.0018 mW - 10 deg. C gradient	Published Study.
Nuclear Reaction	80 mW/cm^3 1E6 mWh/cm^3	Published Data.
Fuel Cells	300 - 500 mW/cm^3 ~4000 mWh/cm^3	Published Data.

With aggressive energy management, ENS might live off the environment.

Communication/Computation Technology Projection

	1999 (Bluetooth Technology)	2004
Communication	(150nJ/bit)	(5nJ/bit)
	1.5mW*	50uW
Computation		~ 190 MOPS
		(5pJ/OP)

Assume: 10kbit/sec. Radio, 10 m range.

Large cost of communications relative to computation continues

Energy Management Issues

- Actuation energy is the highest
  - Strategy: ultra-low-power “sentinel” nodes
    - Wake-up or command movement of mobile nodes
- Communication energy is the next important issue
  - Strategy: energy-aware data communication
    - Adapt the instantaneous performance to meet the timing and error rate constraints, while minimizing energy/bit
- Processor and sensor energy usually less important

MICA mote Berkeley	Transmit	720 nJ/bit	Processor	4 nJ/op
	Receive	110 nJ/bit	~ 200 ops/bit	
WINS node RSC	Transmit	6600 nJ/bit	Processor	1.6 nJ/op
	Receive	3300 nJ/bit	~ 6000 ops/bit	

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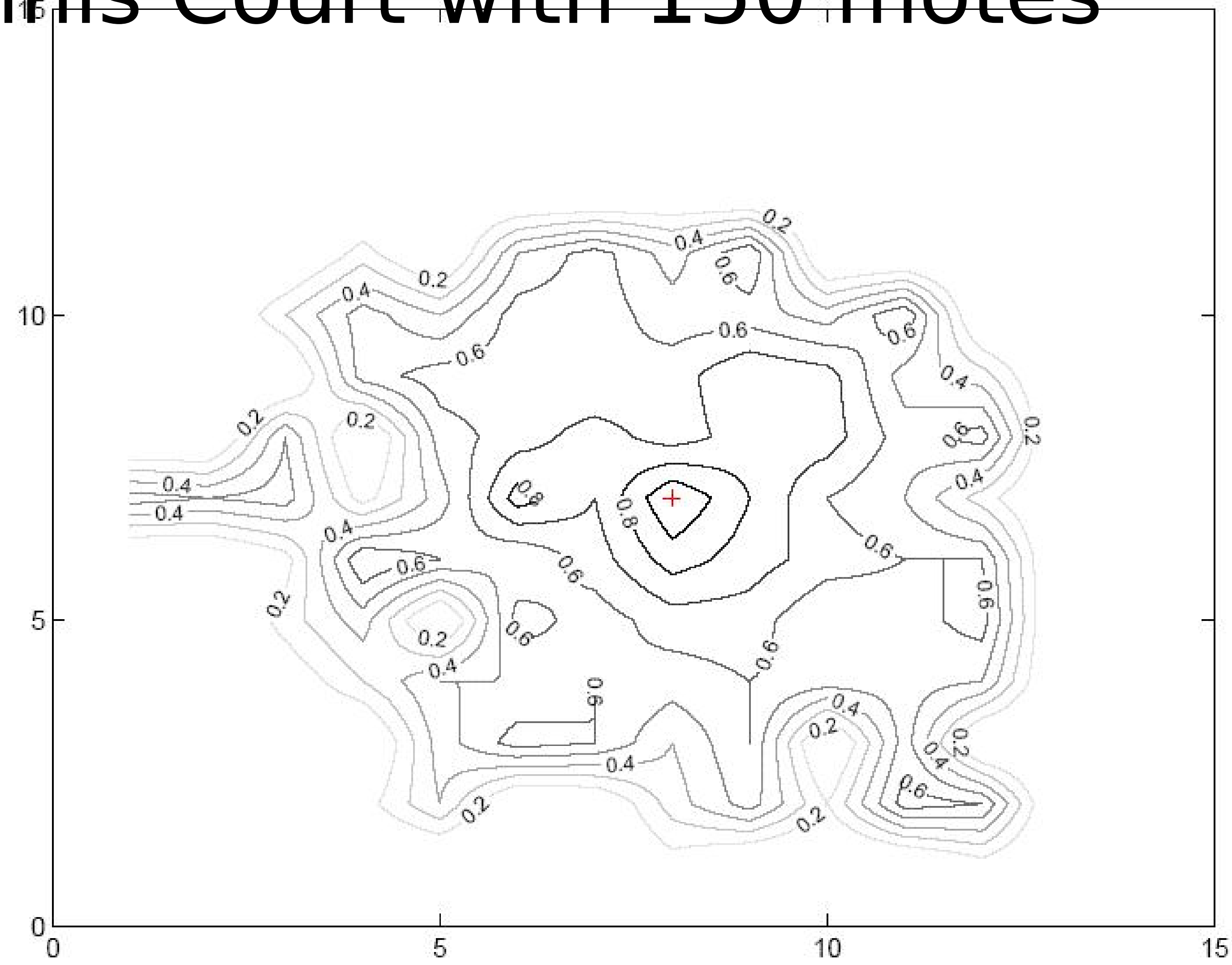
Wireless Sensor Network(WSN) vs. Mobile Ad Hoc Network (MANET)

	WSN	**MANET**
Similarity	Wireless	Multi-hop networking
Security	Symmetric Key Cryptography	Public Key Cryptography
Routing	Support specialized traffic pattern. Cannot afford to have too many node states and packet overhead	Support any node pairs Some source routing and distance vector protocol incur heavy control traffic
Resource	Tighter resources (power, processor speed, bandwidth)	Not as tight.

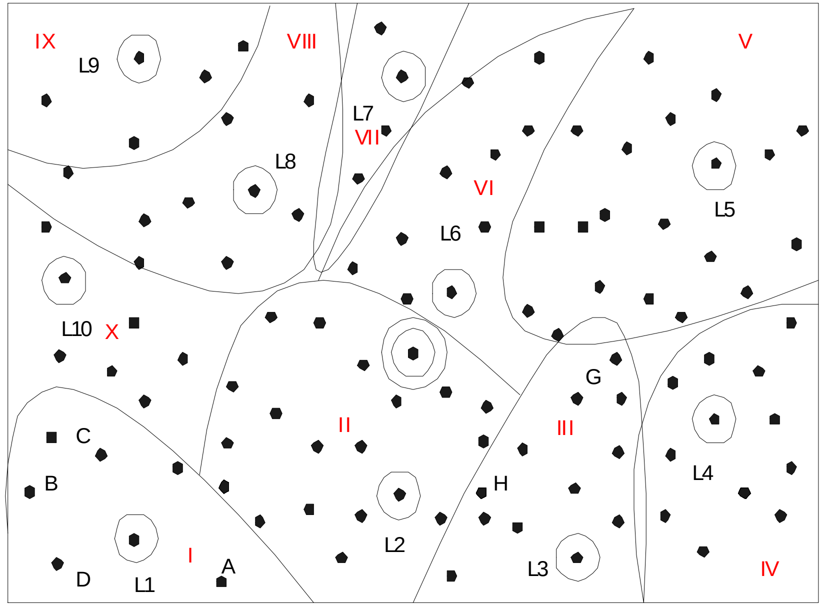
Unusual WSN Link Characteristics
Packet Success Rate Contour
Open Tennis Court with 150 motes

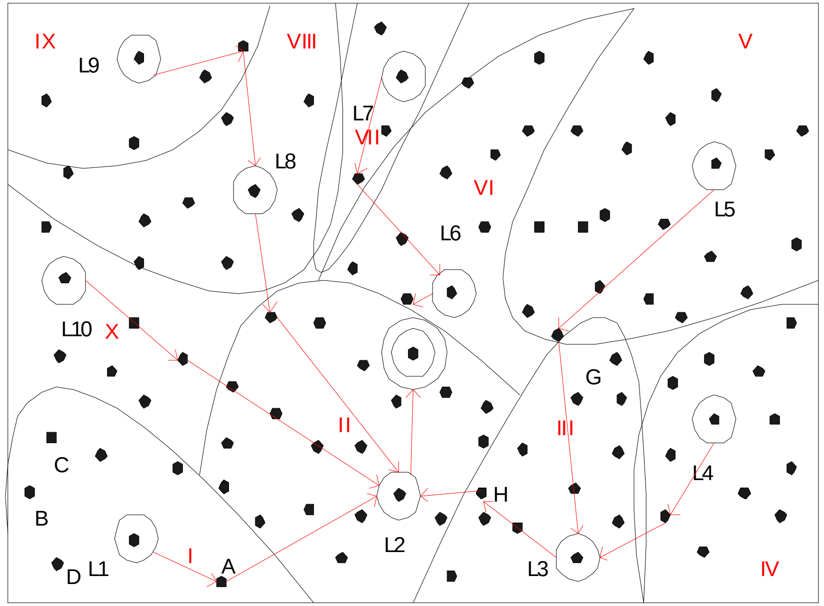


Challenges in Self-organizing Multi-hop Ad-doc Networks

- Problems has been studied in packet radio network and mobile computing.
- However in sensor networks, it is unique in:
  - Lossy short-range wireless ratio
    Need more cross-layer interaction
  - Tight resource constraints
  - Traffic pattern differences
  - In-Network Processing

Cluster /Sink Tree Formation





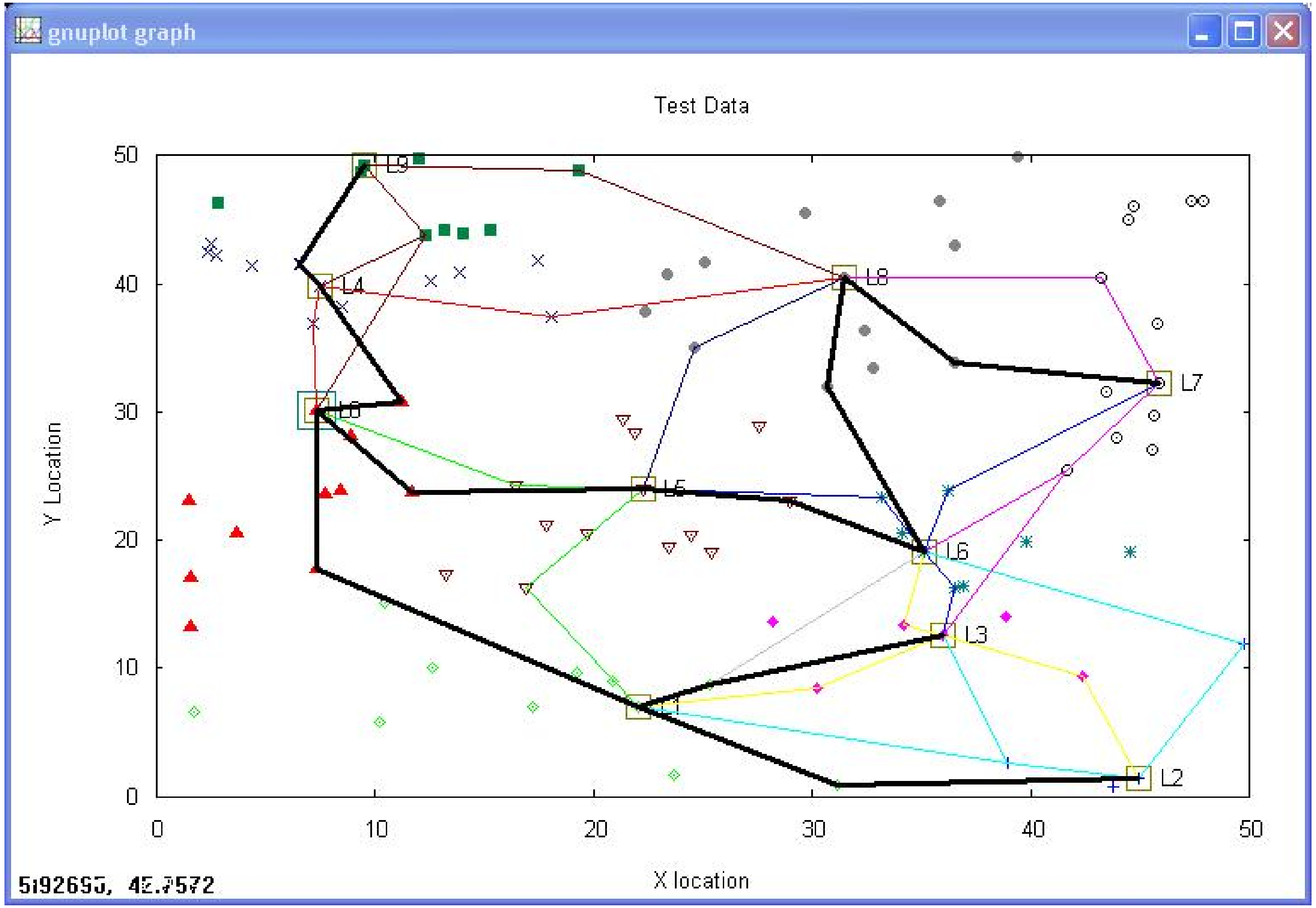
Cluster Formation Phase Sink Tree Formation Phase

Node with Double Circle: Sink Node
Node with Single Circle: Chosen Cluster Leader

Red Arcs forms the sink tree

Should there be direct link between leaders? (Wendi

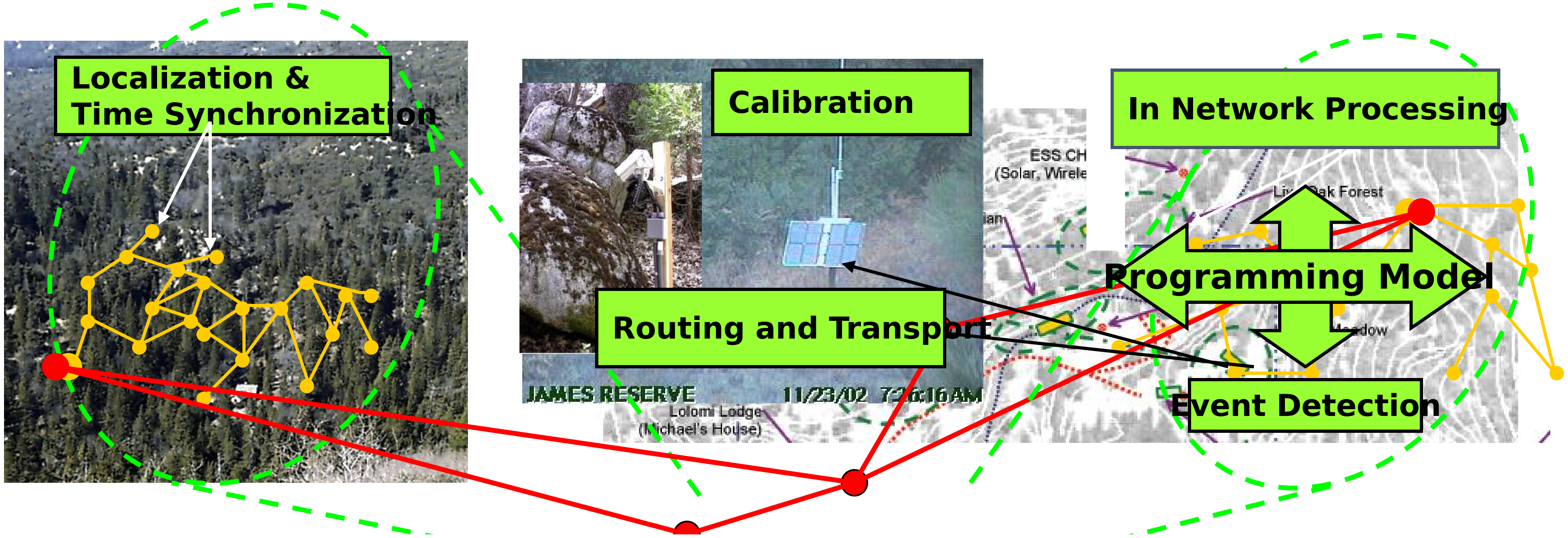
SNATool: Sensor Network Analysis Tool



Cluster/Sink Tree Formation Problems

- How to make cluster size more even?
  All leaders will consume power evenly.
- How to form a sink tree with smallest link distance?
  shorter link less radio power
- How to avoid frequent cluster/sink tree formation?
  avoid disrupt normal data collection traffic
- How to perform tracking responsively?
- How to extend the life time of WSN?
- These are conflict requirements.
  How to resolve it?

Common system services



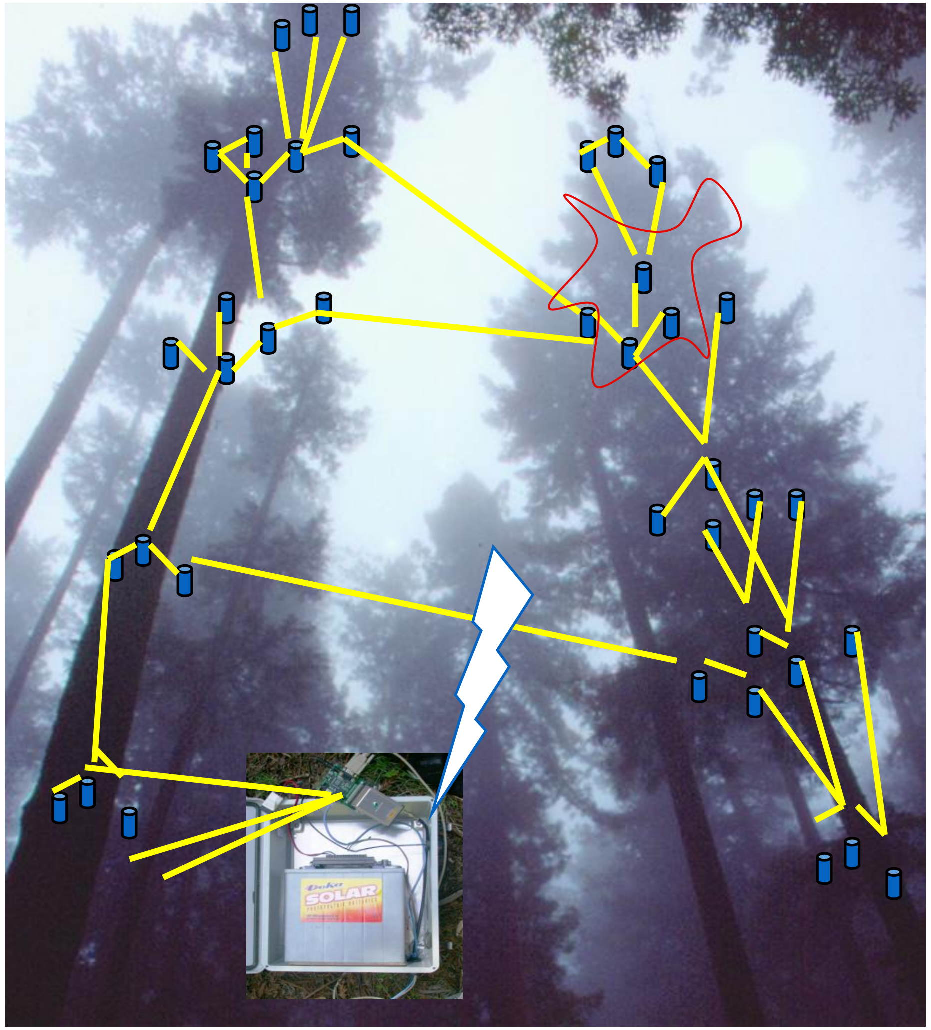
Needed: Reusable, Modular, Flexible, Well-characterized Services/Tools

- Routing and Reliable transport
- Time synchronization, Localization, Calibration, Energy Harvesting
- In Network Storage, Processing (compression, triggering), Tasking
- Programming abstractions, tools

WSN Architecture

- David Culler, Scott Shenker, Ion Stoica, UC Berkely. Creating an Architecture for Wireless Sensor Networks –in a nutshell.

Key Properties



- Networks meaningfully distributed over physical space
- Large numbers of nodes
- Long duration
- Irregular, varying connectivity
- Variations in density
- Loss & interference
- Constrained resources & Energy
- Connected to deeper infrastructure

So how do we go about it?

Wirelss Sensor Network and Pervasive Computing

- D.Raychaudhuri, Rutgers WINLAB. Research Challenges in Sensor Nets and Pervasive Systems. Including a presentation on writing effective grant proposals.

Mobile Sensor Networks

- William J Kaiser, UCLA CENS. On Constrained Actuation for Sensor Networks.
- Challenges
  - Sustainability
- Solutions in Constrained Actuation and Infrastructure
  - Limited dimension, limited range mobility
  - Infrastructure-supported mobility
- New Research Area
  - Adaptive sampling and deployment
  - Coordinated mobile embedded sensors
  - Adaptation of network resources
  - Active Fusion

Networked Infomechanical Systems (NIMS)

- **Networked mobile nodes**
  - Sensing
  - Sampling
  - Energy logistics
  - Communication
- **Infrastructure**
  - Deterministic and precise motion
  - 3-D volume access
  - Mass transport at low energy
- ***System Ecology for Sustainability***
  - Fixed nodes
  - Mobile nodes
  - Infrastructure

System Ecology : Introduces New Design Rules

Tiers	Sensing Accuracy	Energy Efficiency	Spatial Coverage	Temporal Coverage
Mobile Nodes	Adaptive Topology and Perspective	Low Energy Transport/ Comm	Both Sensing and Sampling in 3-D	Enable Long Term Sustainability
Connected Fixed Nodes	Optimal, Precise Deployment	Energy Production and Delivery	Optimized Location in 3-D	Continuous, In Situ Sensing-Sampling
Untethered Fixed Nodes	Localized Sensing and Sampling	Alert and Guide Mobile Assets	Access to Non-Navigable Areas	Continuous Low Energy Vigilance

Security and Privacy in Sensor Networks: Research Challenges

- Radha Poovendran, U. Washington.
- Resource constrains on WSN devices. Energy, computation, memory

WSN Education

- Waylon Brunette, U. Washington. The Flock project.