Algorithms for
Wireless Ad Hoc and Sensor Networks

Partha Sarathi Mandal
Department of Mathematics
IIT Guwahati

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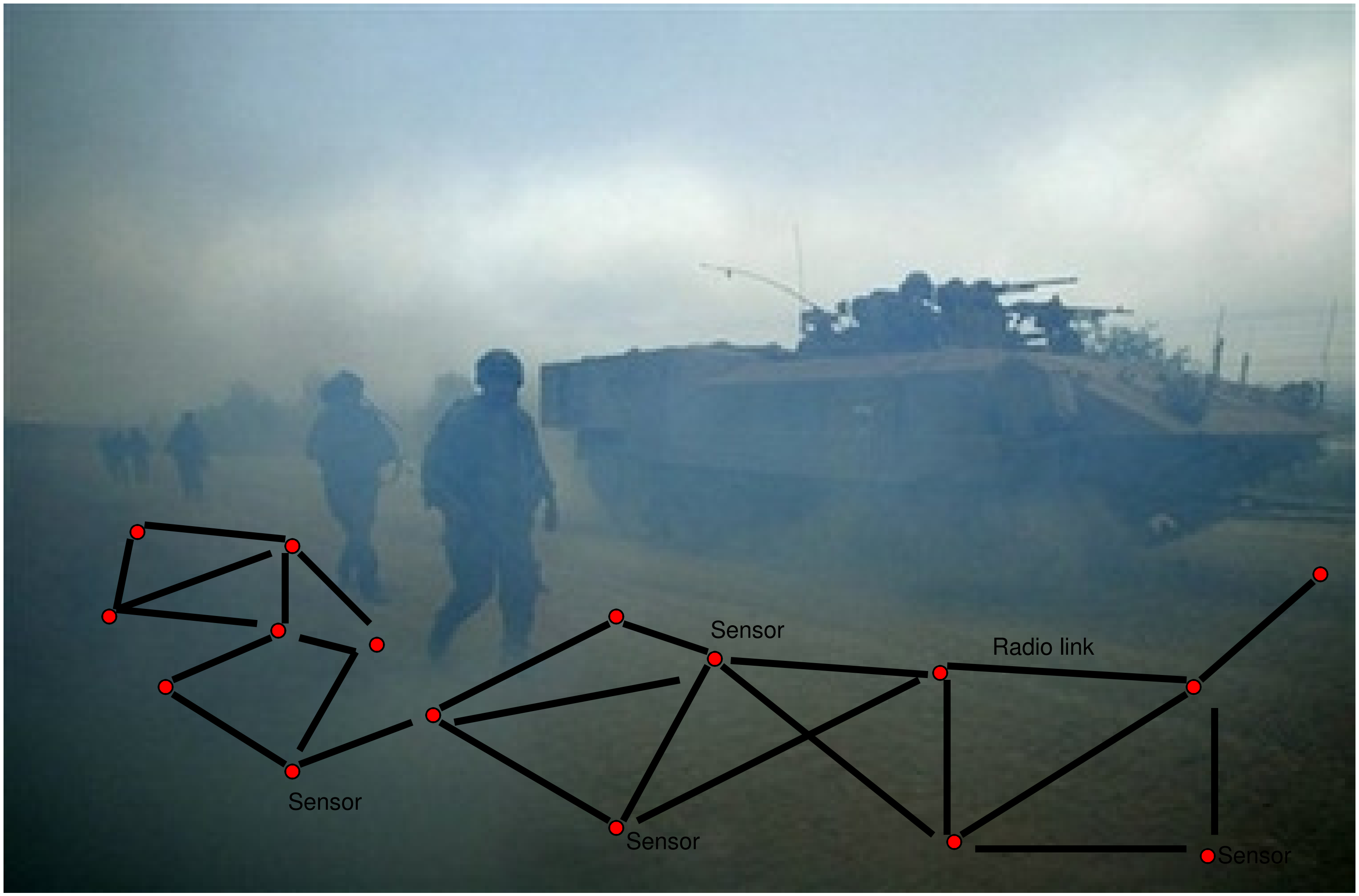
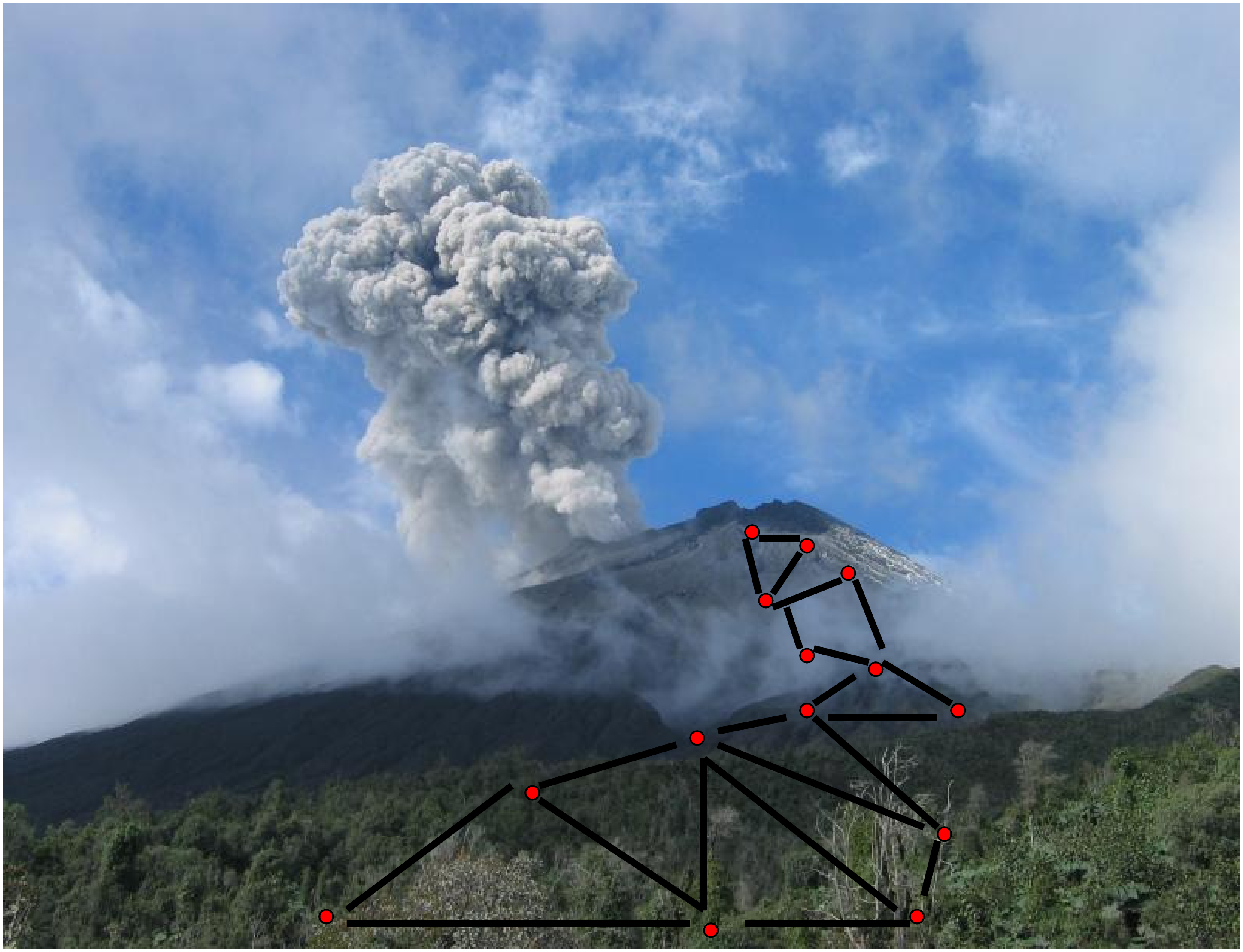
Thanks! ☺

Motivation



Credits: OTB News

Motivation



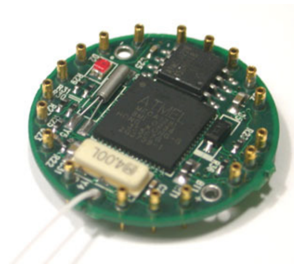
Credits: Matt Welsh (Harvard)

Motivation

Credits: www.visitingdc.com

Enabling Technology?

Mica2



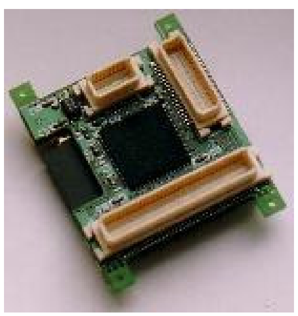
Mica Dot

Telos

ETag

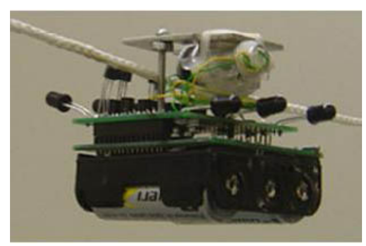
Mica Mote

Pluto



DSYS25

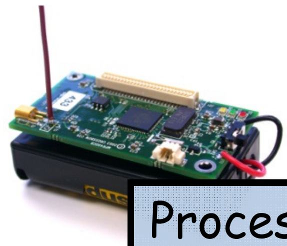
BT Node

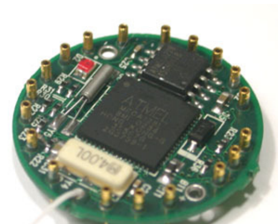


XYZ

EmberNet

Enabling Technology?


Mica2

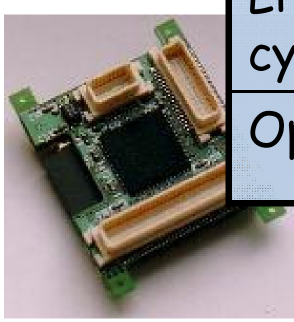

Mica Dot


Telos


ETag


Pluto

Processor	ATmega128, 8-bit, 16MHz
RAM	4KB
Program Memory	128KB
External Flash Memory	512KB
Radio Transceiver	(60kbps, 250kbps)
Lifetime (2AA, no duty-cycle)	~6 days
Operating Environment	Untethered, Harsh


DSYS25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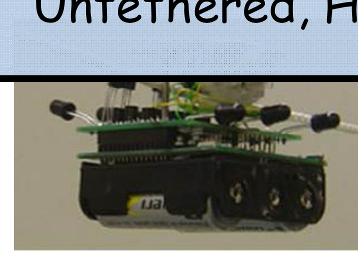
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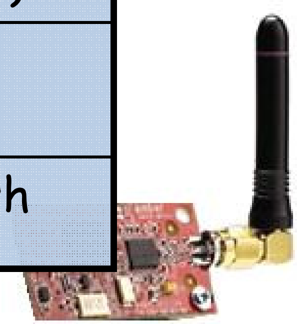
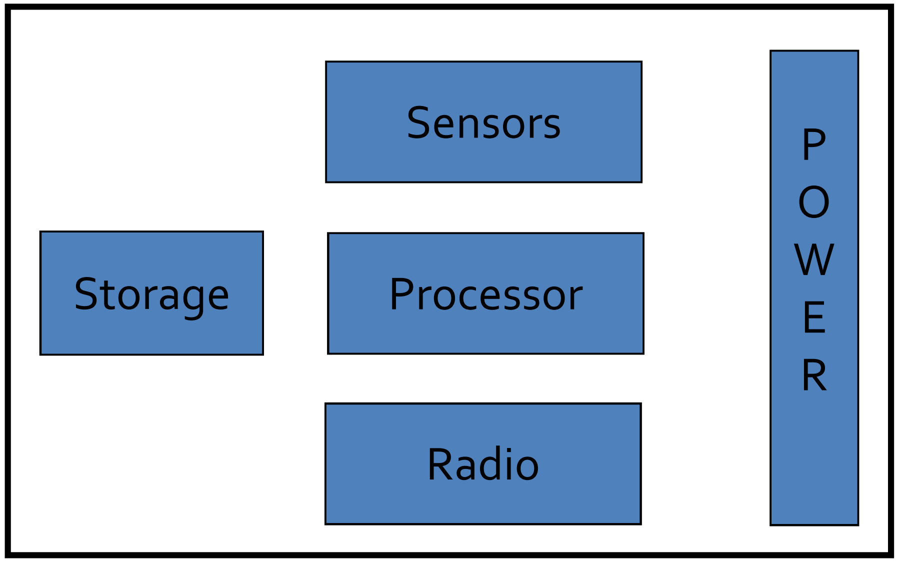

EmberNet

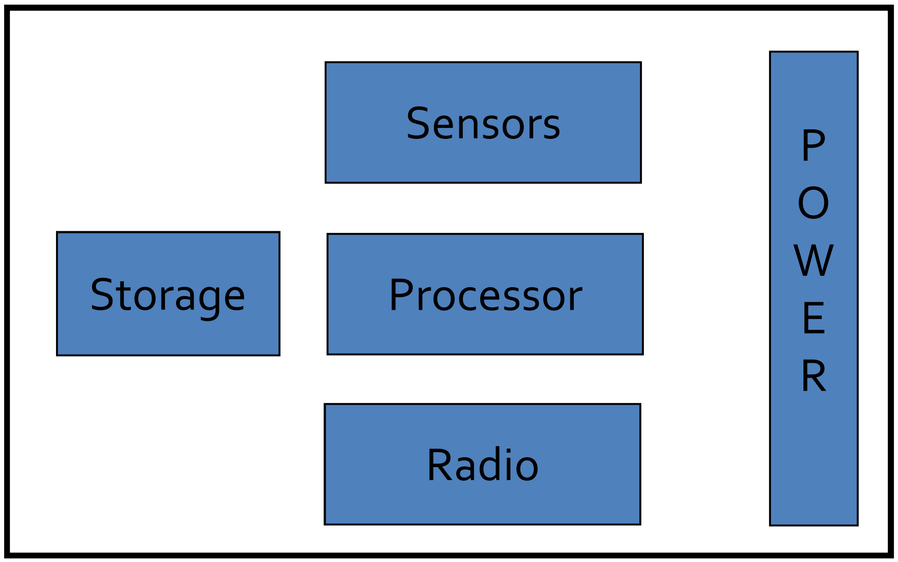
Wireless Sensor Networks (WSNs)

- Networks of typically small, battery-powered, wireless devices.
  - On-board processing,
  - Communication, and
  - Sensing capabilities.



WSN device schematics

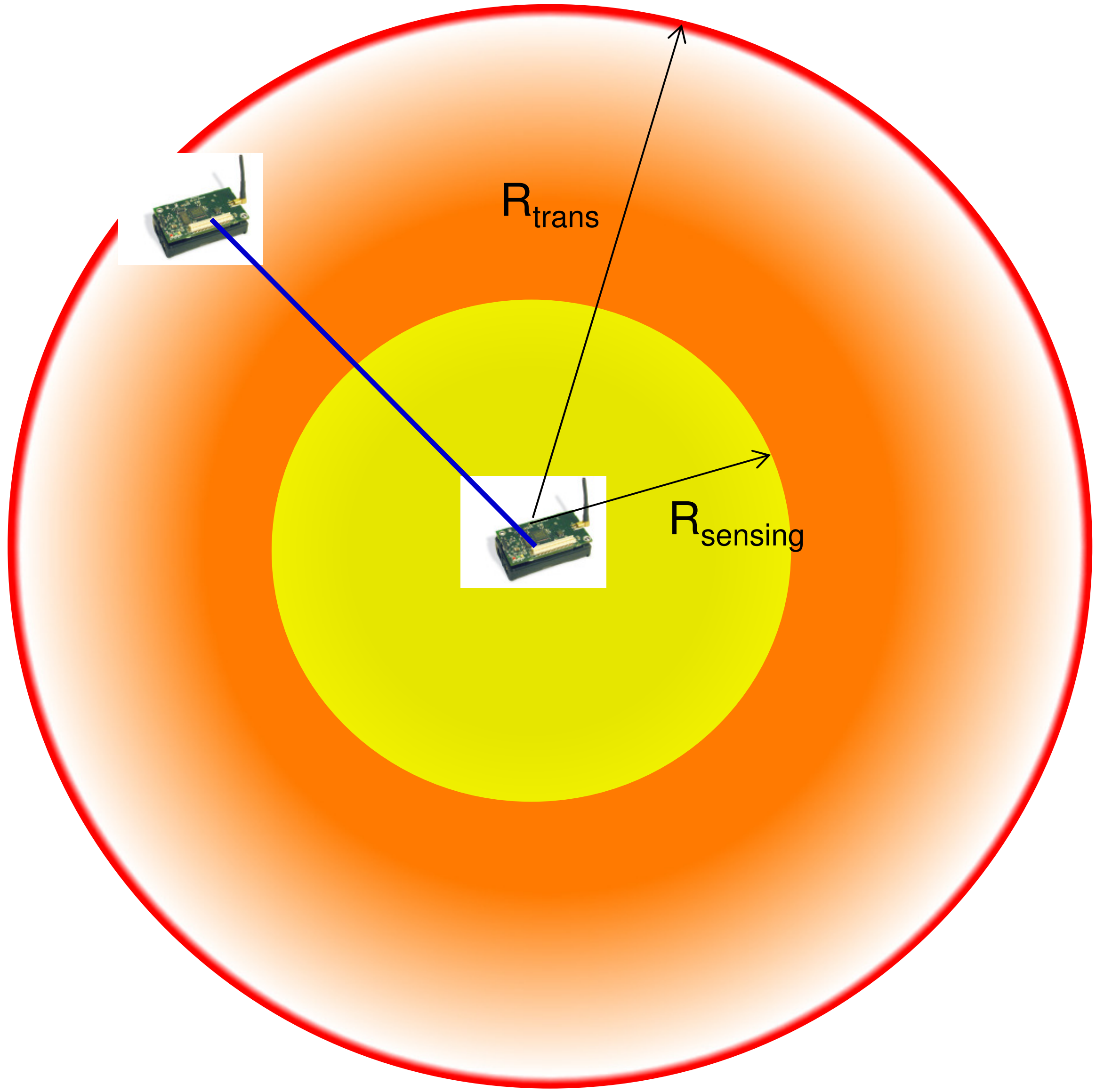
WSN node components



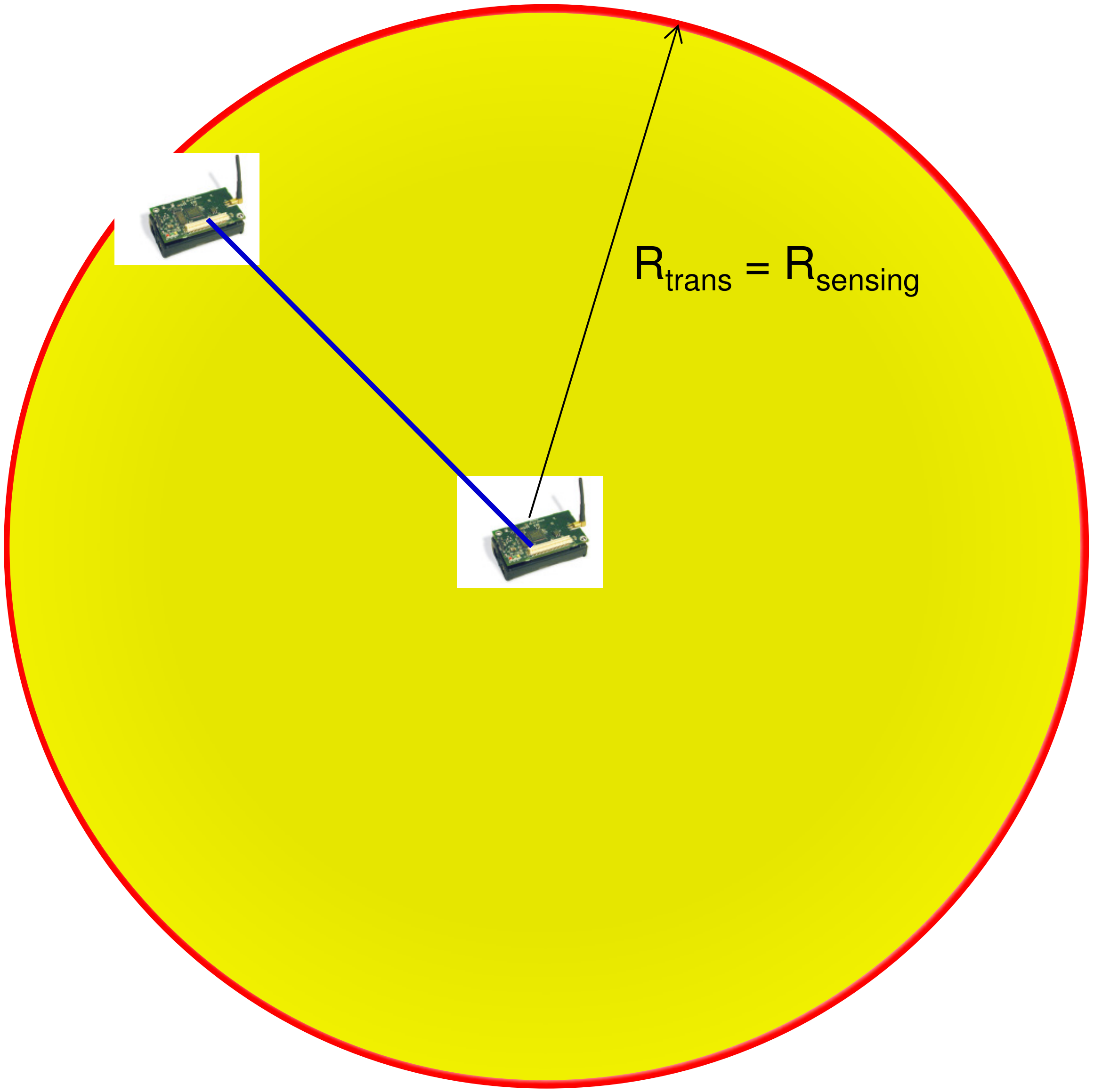
WSN device schematics

- Low-power processor.
  - Limited processing.
- Memory.
  - Limited storage.
- Radio.
  - Low-power.
  - Low data rate.
  - Limited range.
- Sensors.
  - Scalar sensors: temperature, light, etc.
  - Cameras, microphones.
- Power.

Transmission range and sensing range



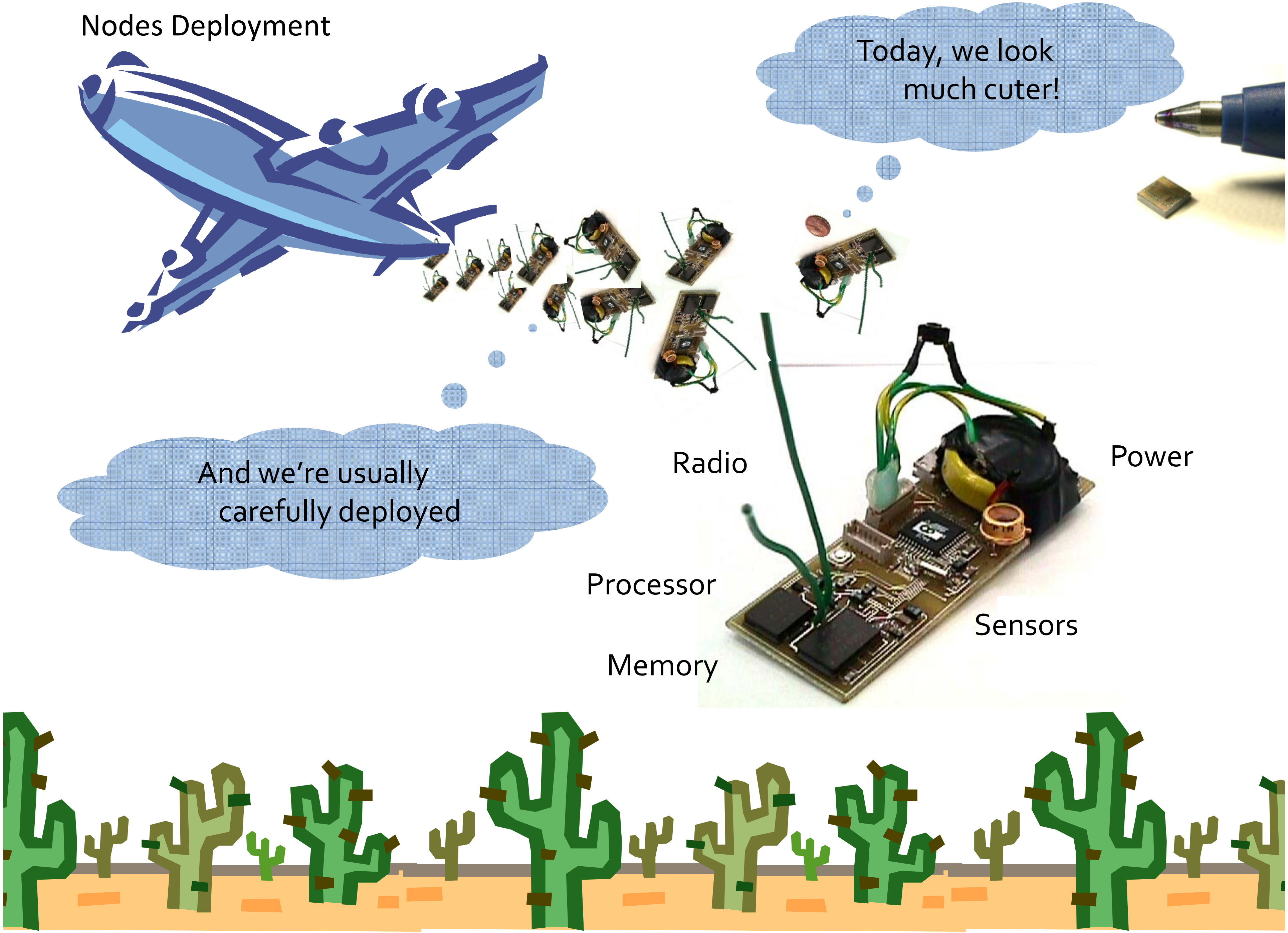
Transmission range and sensing range



Advances in Wireless Sensor Nodes

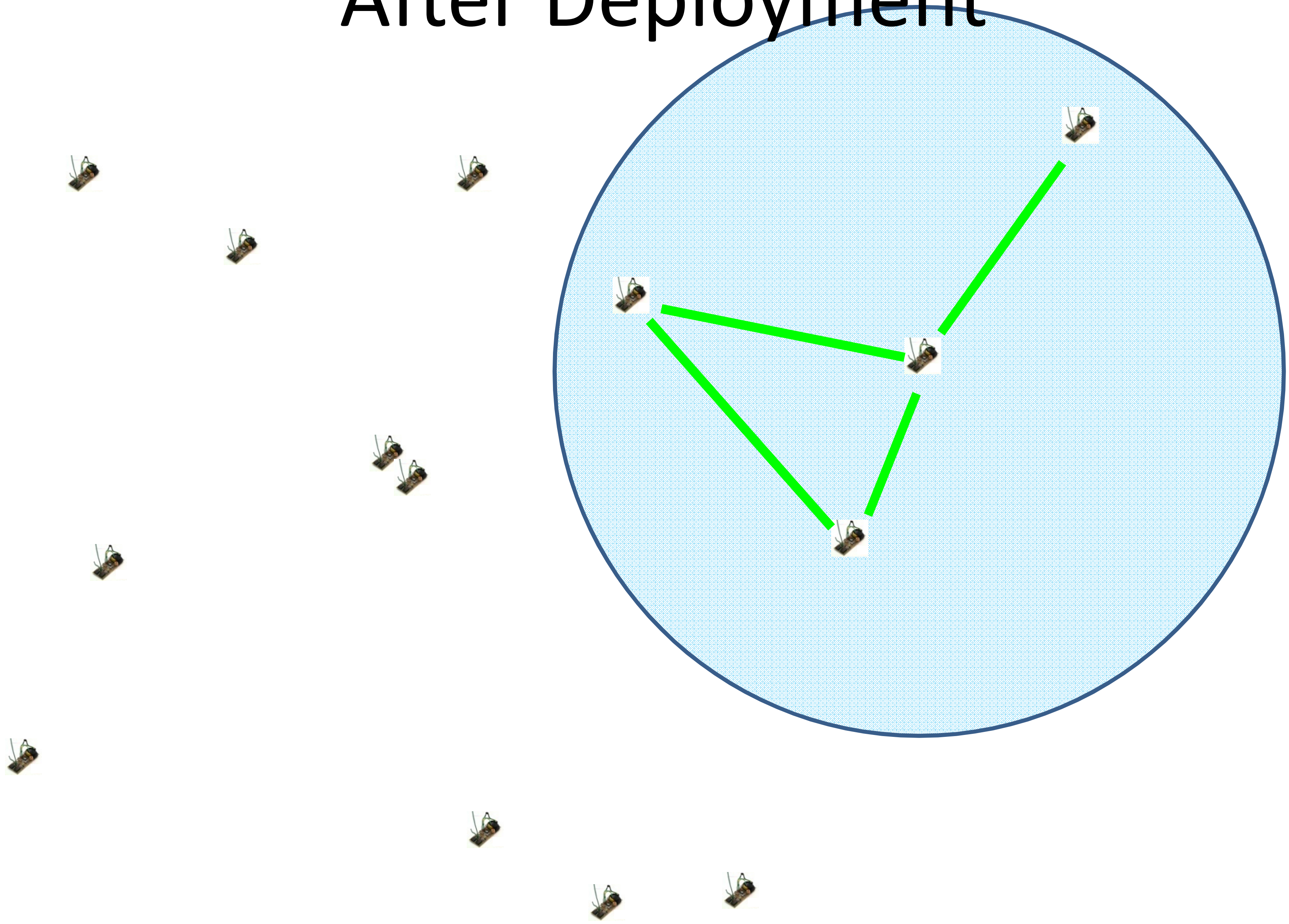
Consider Multiple Generations of Berkeley Motes

Model	Rene	Mica	Mica-2	Mica-Z	IRIS
Date	1999	2002	2003	2004	2010
CPU	4 MHz	4 MHz	4 MHz	4 MHz	2.4 GHz
Flash Memory	8 KB	128 KB	128 KB	128 KB	128 KB
RAM	512 B	4 KB	4 KB	4 KB	8 KB
Radio	10 Kbps	40 Kbps	76 Kbps	250 Kbps	250 kbps

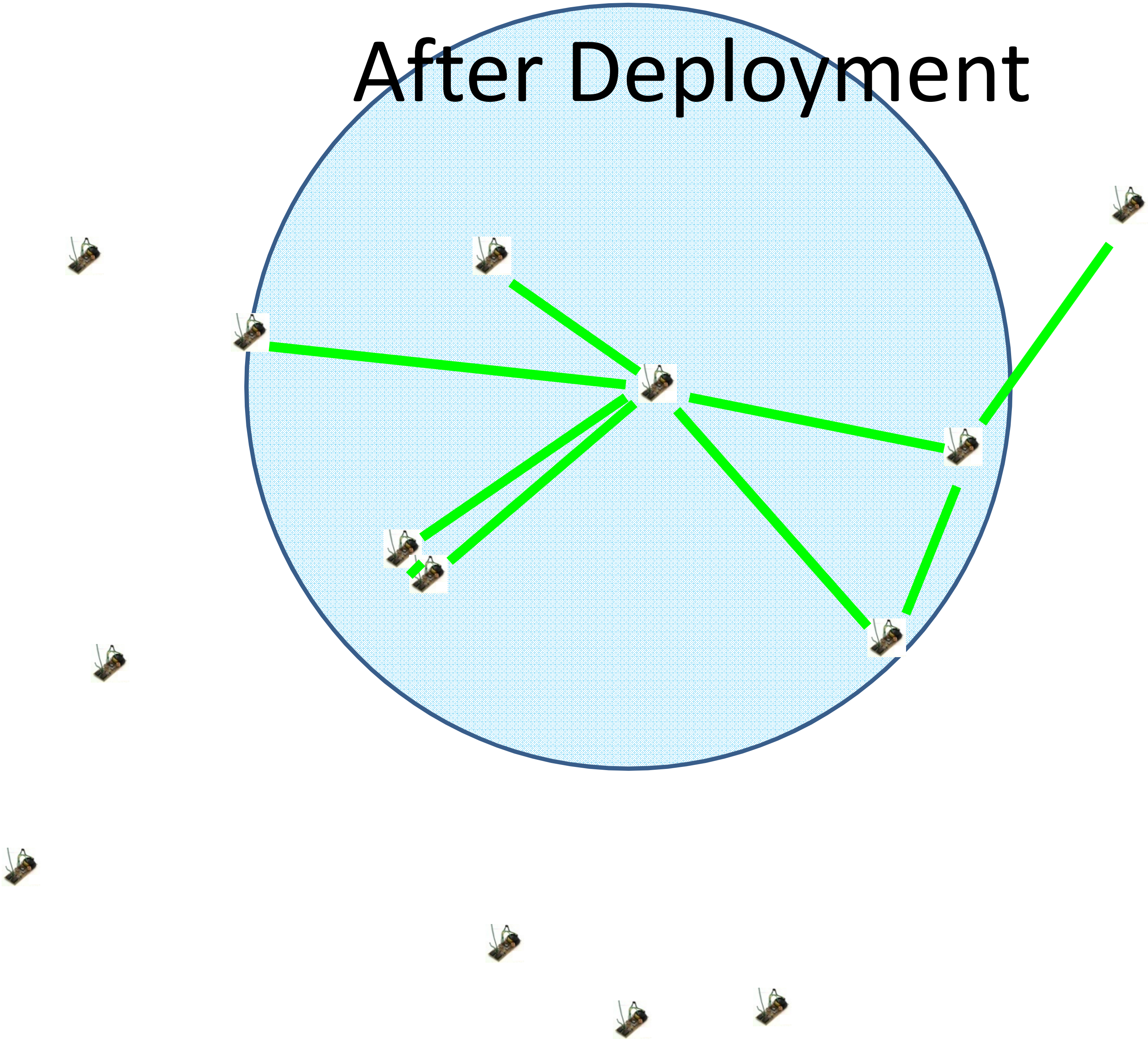

Nodes Deployment
Today, we look much cuter!
And we're usually carefully deployed
Radio
Power
Processor
Sensors
Memory

After Deployment

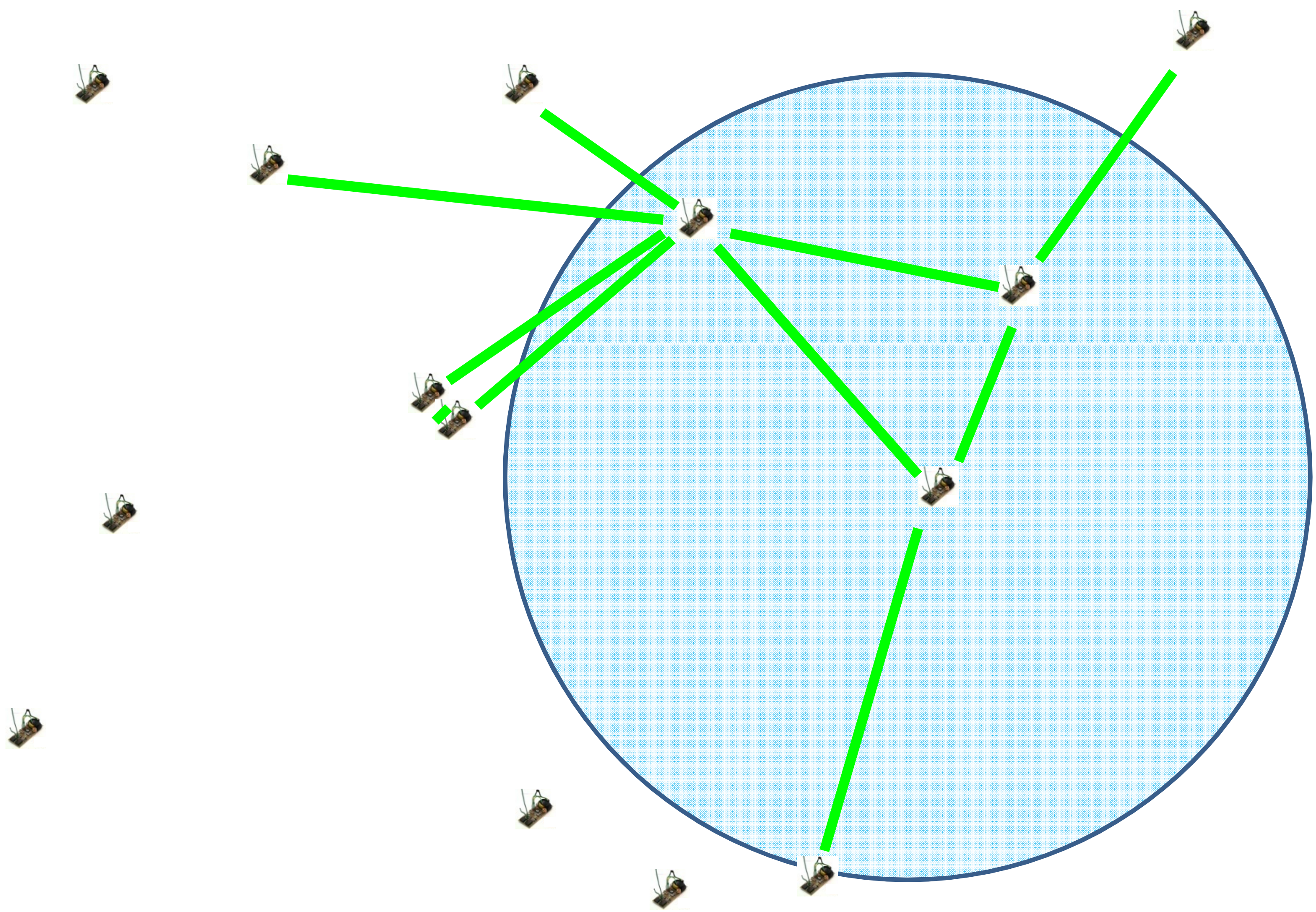
After Deployment



After Deployment



After Deployment



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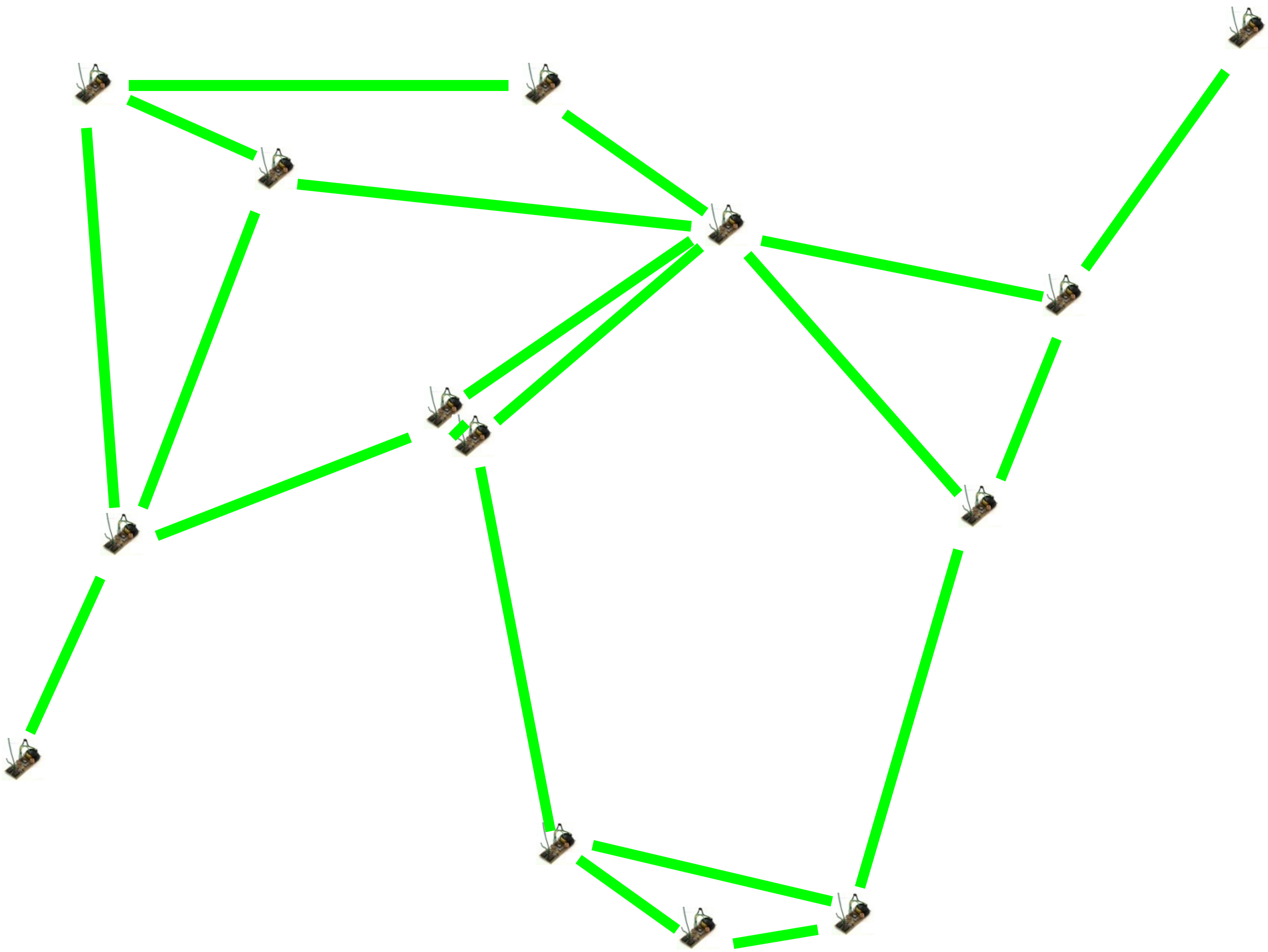


Ad Hoc Networks vs. Sensor Networks

- Laptops, PDA's, cars, soldiers
- All-to-all routing
- Often with mobility (MANET's)
- Trust/Security an issue
  - No central coordinator
- Maybe high bandwidth

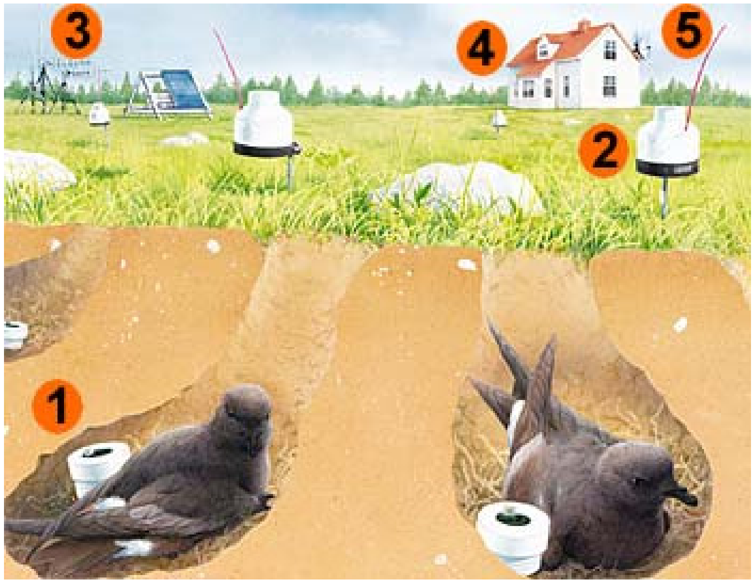
- Tiny nodes: 4 MHz, 32 kB, …
- Broadcast/Echo from/to sink
- Usually no mobility
  - but link failures
- One administrative control
- Long lifetime → Energy

There is no strict separation; more variants such as mesh or sensor/actor networks exist

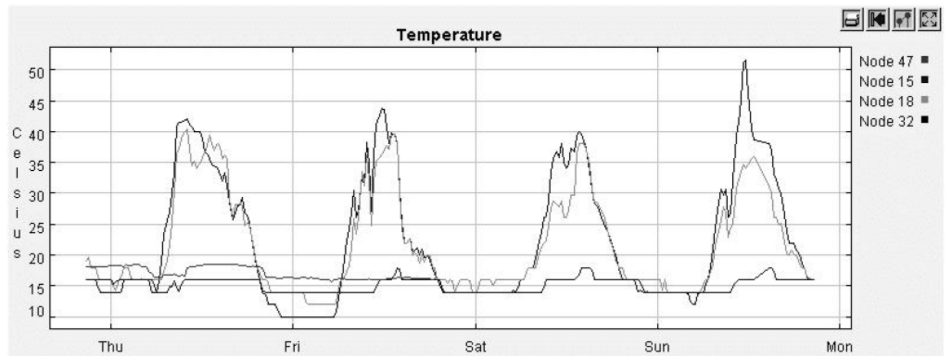
Applications

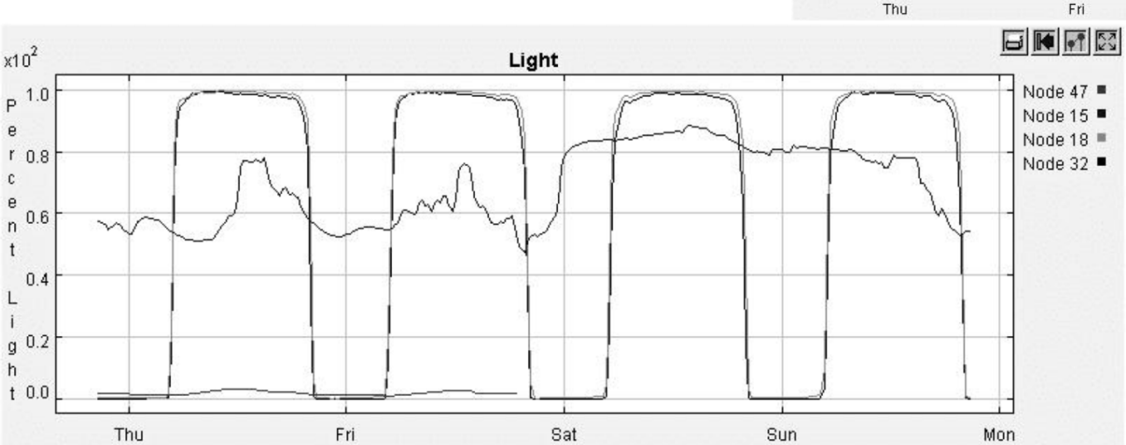
Applications

Animal Monitoring (Great Duck Island)

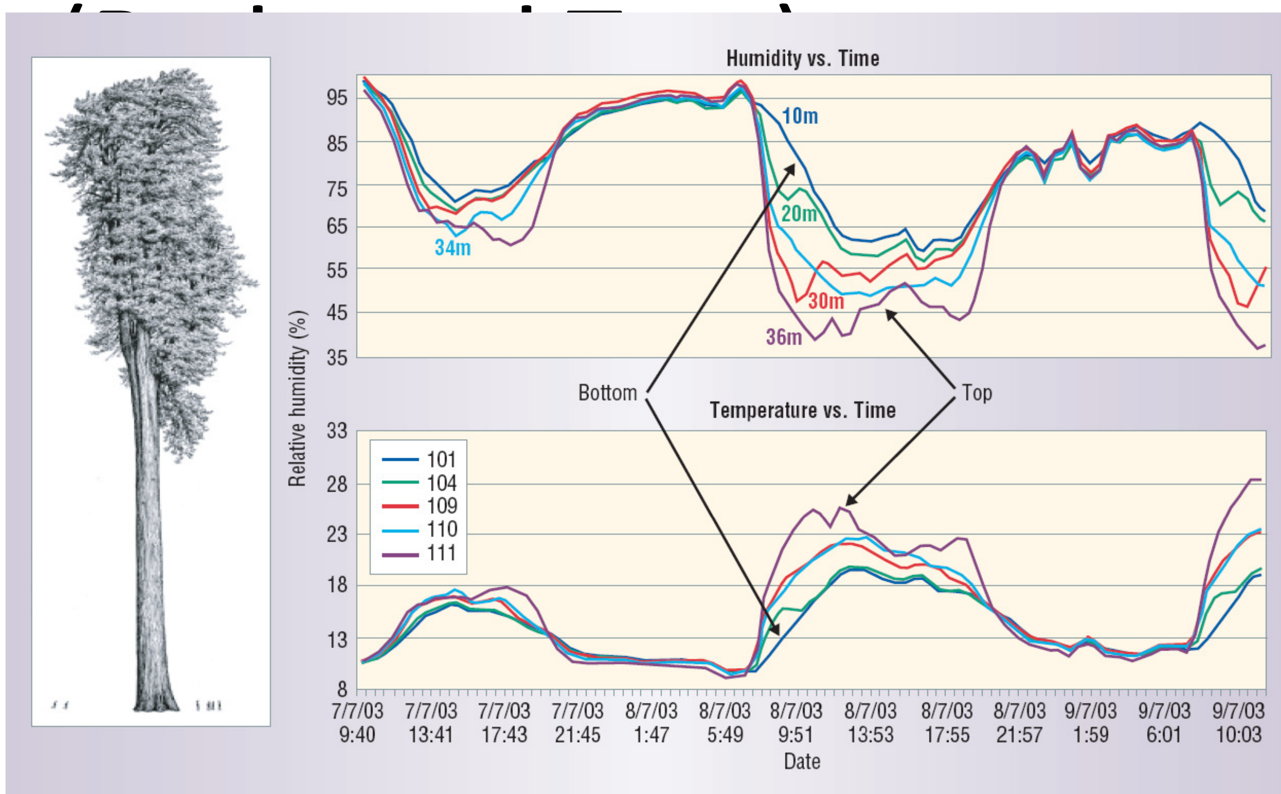


1. Biologists put sensors in underground nests of storm petrel
2. And on 10cm stilts
3. Devices record data about birds
4. Transmit to research station
5. And from there via satellite to lab





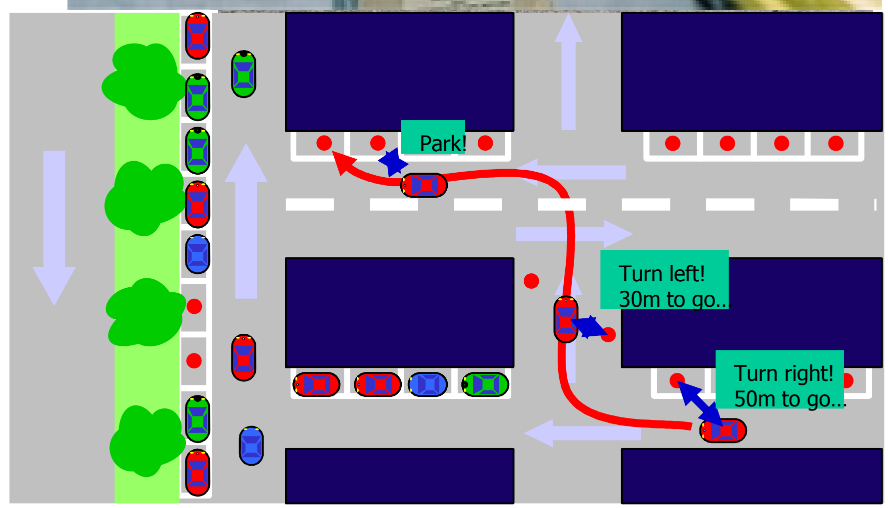
Environmental Monitoring



- Microclimate in a tree
- 10km less cables on a tree; easier to set up
- Sensor Network = The New Microscope?

Smart Spaces (Car Parking)

- The good: Guide cars towards empty spots
- The bad: Check which cars do not have any time remaining
- The ugly: Meter running out: take picture and send fine



[Matthias Grossglauser, EPFL & Nokia Research]

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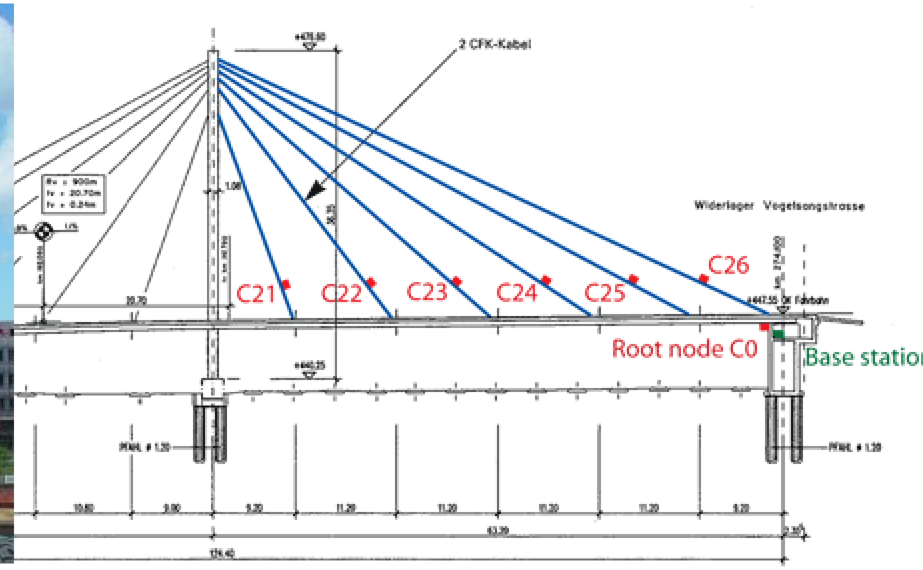
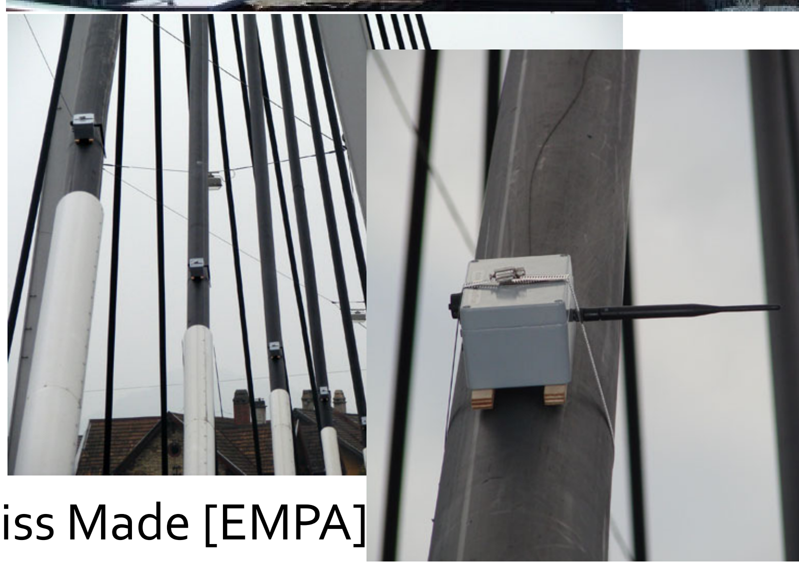
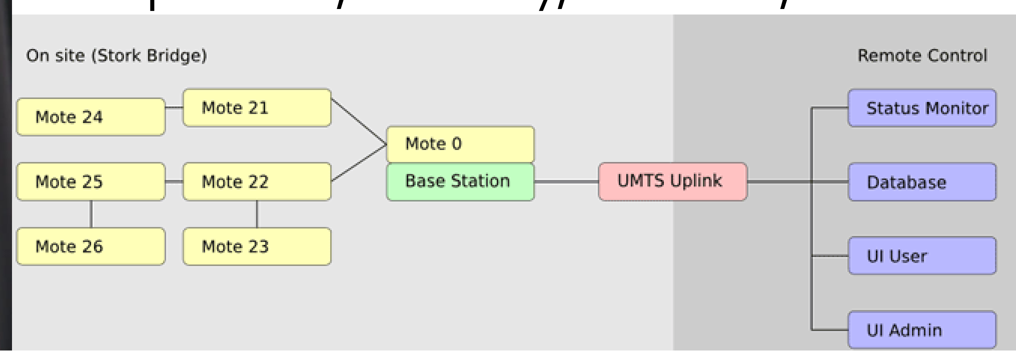
Structural Health Monitoring (Bridge)





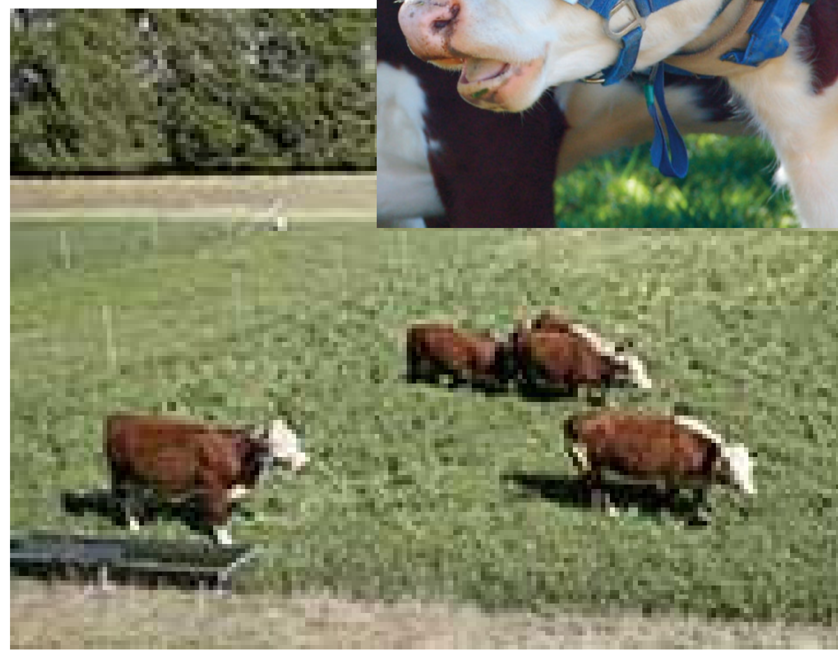
Swiss Made [EMPA]

Detect structural defects, measuring temperature, humidity, vibration, etc.



Virtual Fence (CSIRO Australia)

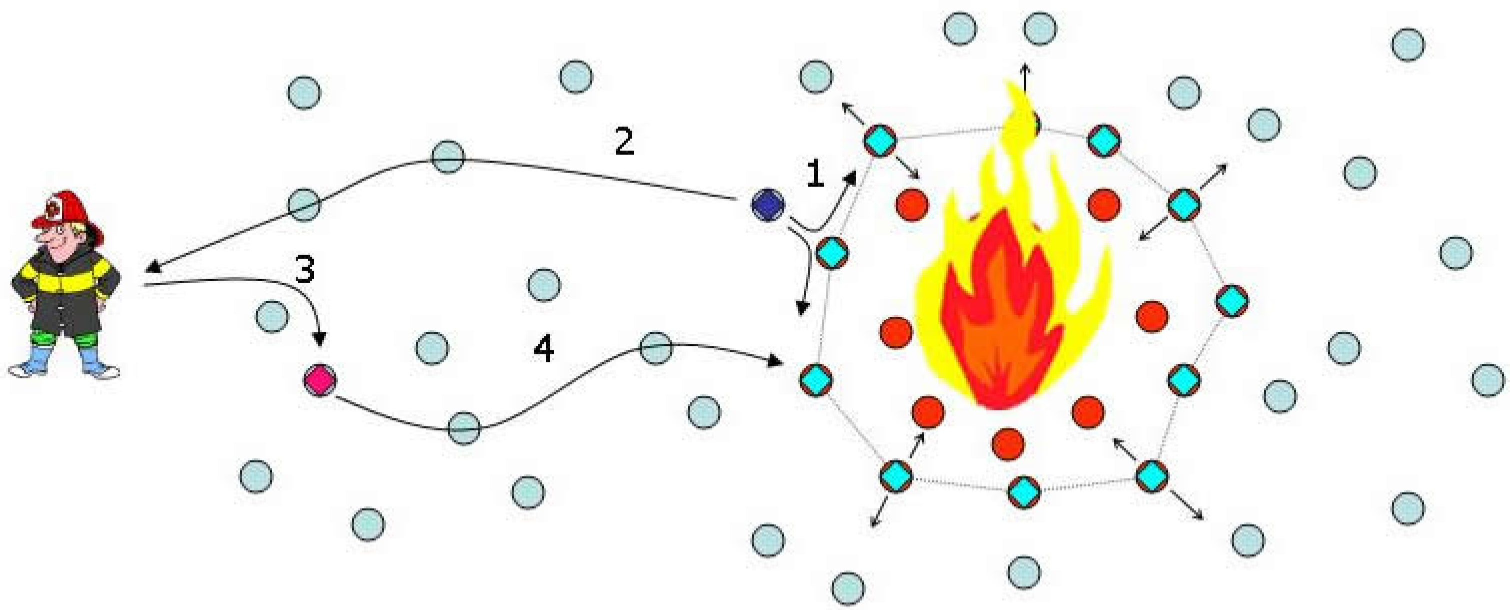
- Download the fence to the cows. Today stay here, tomorrow go somewhere else.
- When a cow strays towards the co-ordinates, software running on the collar triggers a stimulus chosen to scare the cow away, a sound followed by an electric shock; this is the “virtual” fence. The software also "herds" the cows when the position of the virtual fence is moved.
- If you just want to make sure that cows stay together, GPS is not really needed…



Cows learn and need not to be shocked later… Moo!

Wild Fire detection

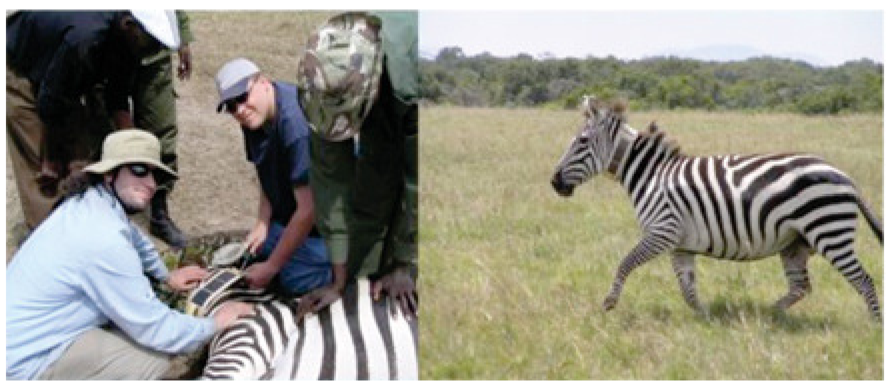
1. Wild fire tracking until a perimeter has been formed.
2. A notification is sent to a fire fighter notifying him of the fire's location.
3. The fire fighter injects a guidance agent into



Habitat Monitoring

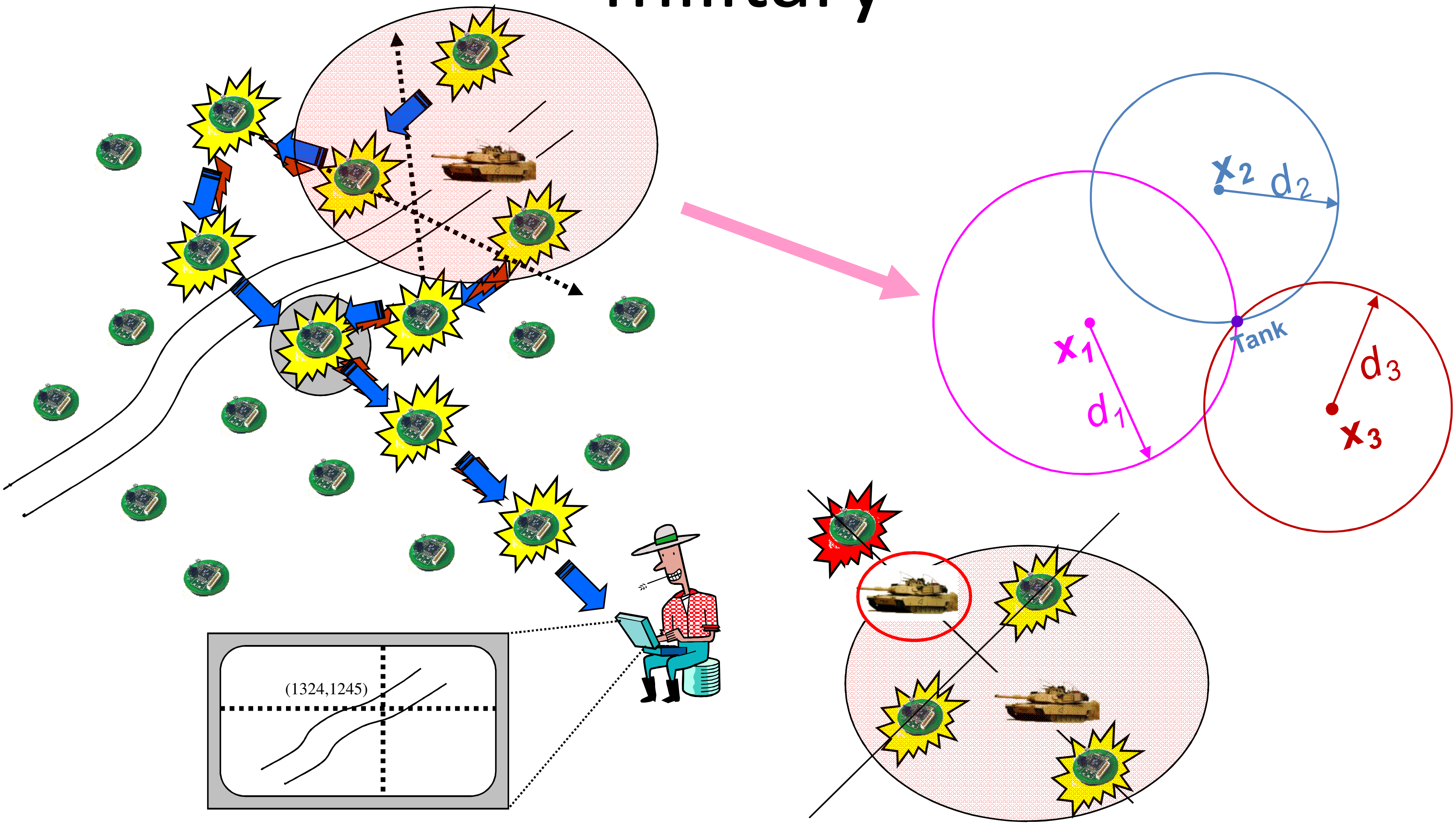
- The ZebraNet Project

  Collar-mounted sensors monitor zebra movement in Kenya



Source: Margaret Martonosi, Princeton University

Surveillance and tracking for military



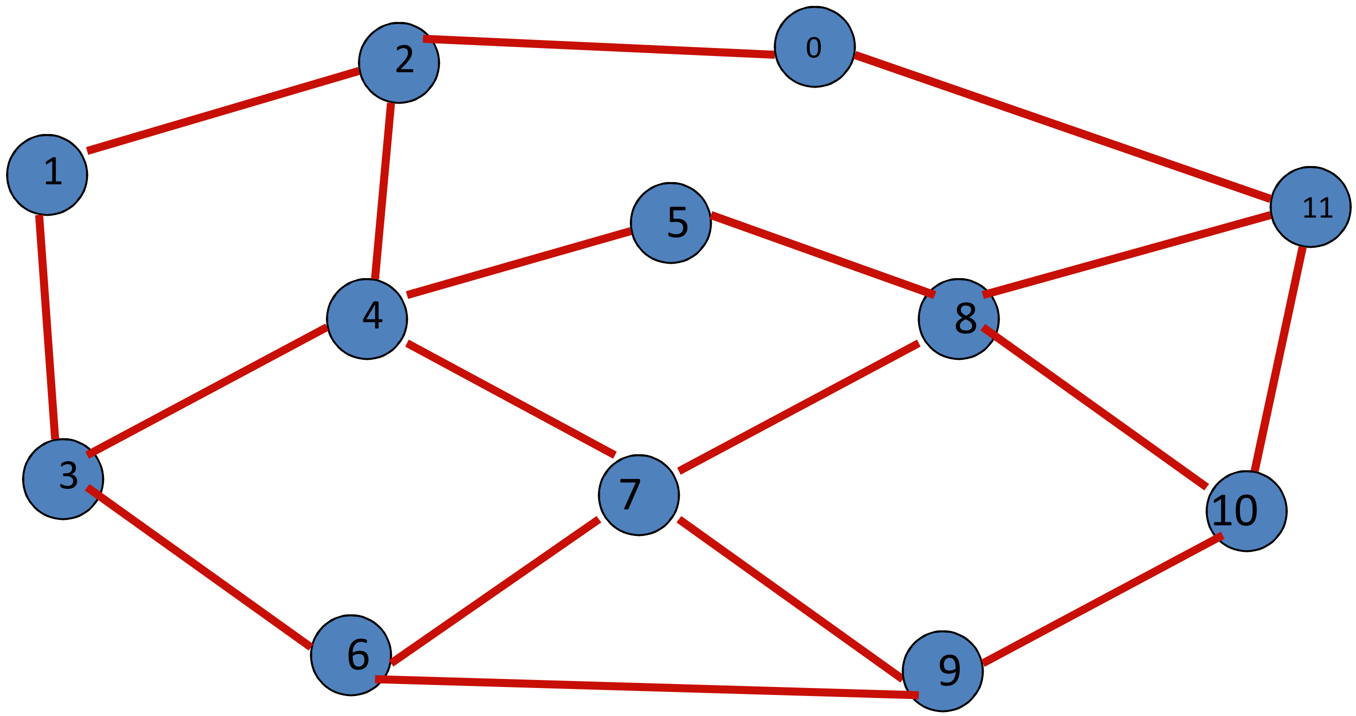
Some basic ideas about Distributed System

- What is Distributed System ?
- A broad definition
  - A set of autonomous processes that communicate among themselves to perform some task
- Modes of communication
  - Message passing
  - Shared memory
- Includes single machine with multiple communicating processes also

Some basic ideas about Distributed System

- What is Distributed System ?
- Distributed system is a collection of independent processes that communicate with each other and cooperate to achieve a common goal.
- A process is set of instructions and variables.
- Each process can proceed with its own speed.
- The only way for one process to coordinate with others is via communication.
- Thus the system consists of a set of processes connected by a network of communication links.

What is Distributed System?



- The **nodes** are processes, and the **edges** are communication channels. It is a **network** of processes.

Why are WSNs challenging from a research point of view?

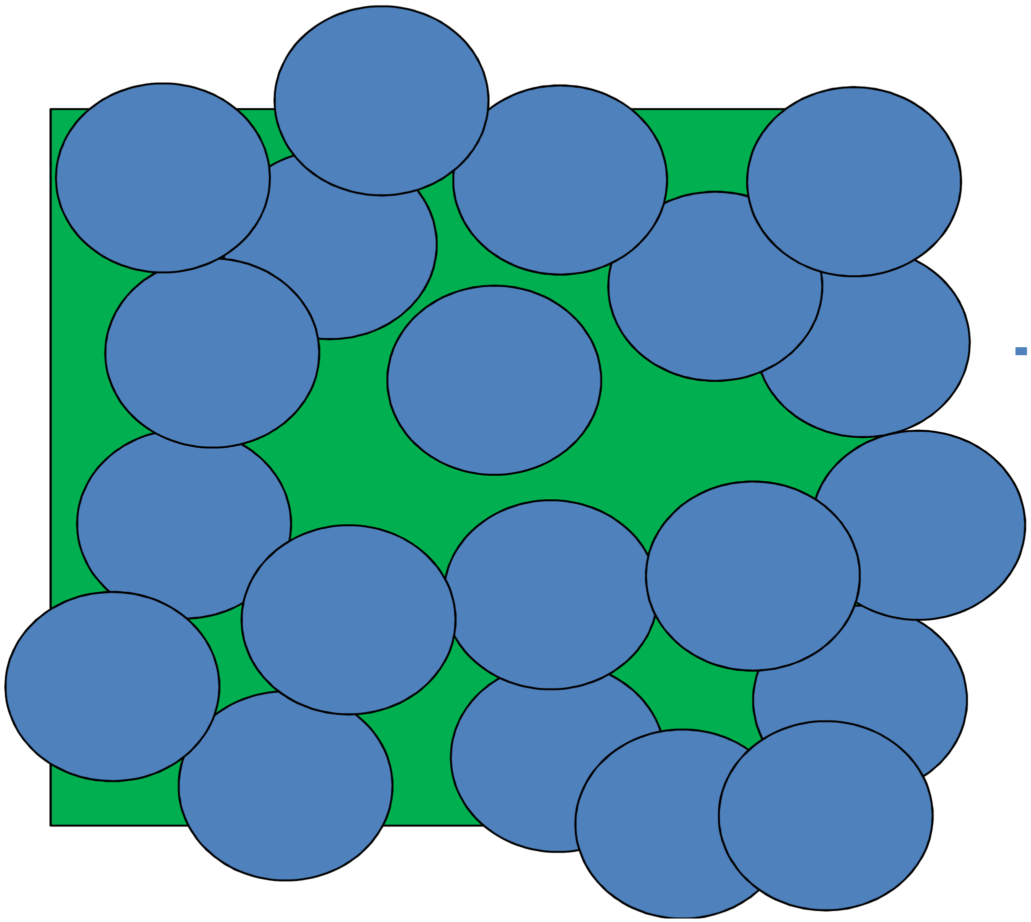
- Typically, severely energy constrained
  - Limited energy sources (e.g., batteries).
  - Trade-off between performance and lifetime.
- Self-organizing and self-healing
  - Remote deployments.
- Scalable
  - Arbitrarily large number of nodes.
- Heterogeneity
  - Devices with varied capabilities.
  - Hierarchical deployments.
- Adaptability
  - Adjust to operating conditions and changes in application requirements.
- Time synchronization
- Security and privacy
  - Potentially sensitive information.
  - Hostile environments.

Localization & Positioning

- Why positioning ?
  - Sensor nodes without location information are often meaningless
  - Avoid having "costly" positioning hardware
  - Geo-routin
- Why not GPS ?
  - "Heavy, large, and expensive"
  - Battery drain
  - Not indoors
  - Accuracy?
- Solution: equip small fraction with GPS (anchors)

Coverage

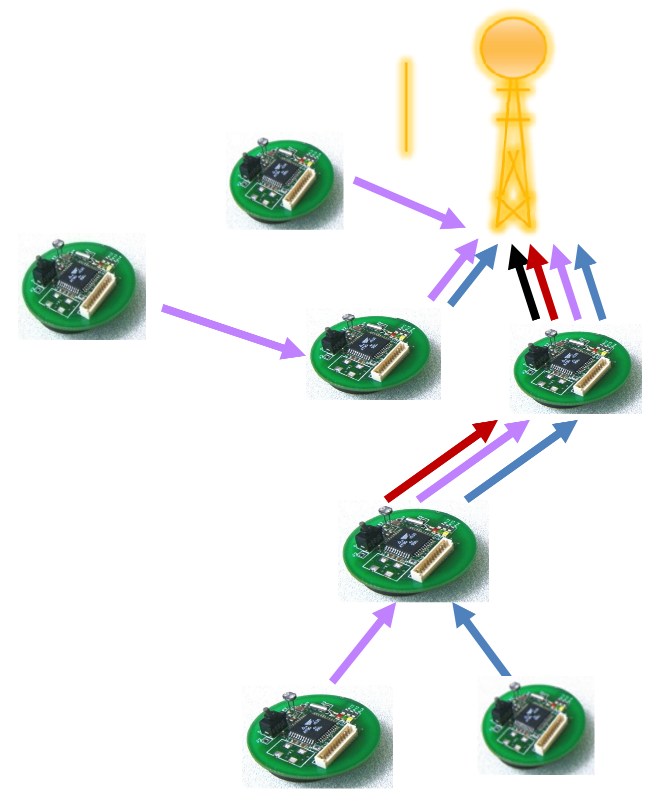
- After deployment we should check whether the region is fully covered by the sensor nodes or not.



Data Aggregation

- Data aggregation is a route to the sink, on which nodes combine their own measurement with the ones of other nodes in proximity.

- No. of packets without aggregation is 13



Data Aggregation

- Data aggregation is a route to the sink, on which nodes combine their own measurement with the ones of other nodes in proximity.

- No. of packets without aggregation is 13
- No. of packets with aggregation is 7
- Reduction of packets by aggregation