

# Wireless Sensor Networks: Application Developers Perspective

Cross Layer Melting Approach

C-DAC  
@  
UbiComp India 2008



# Technological Blend

WeC 1/00



Rene 11/00



Mica 1/02



Mica2 9/02



Mica2dot 9/02



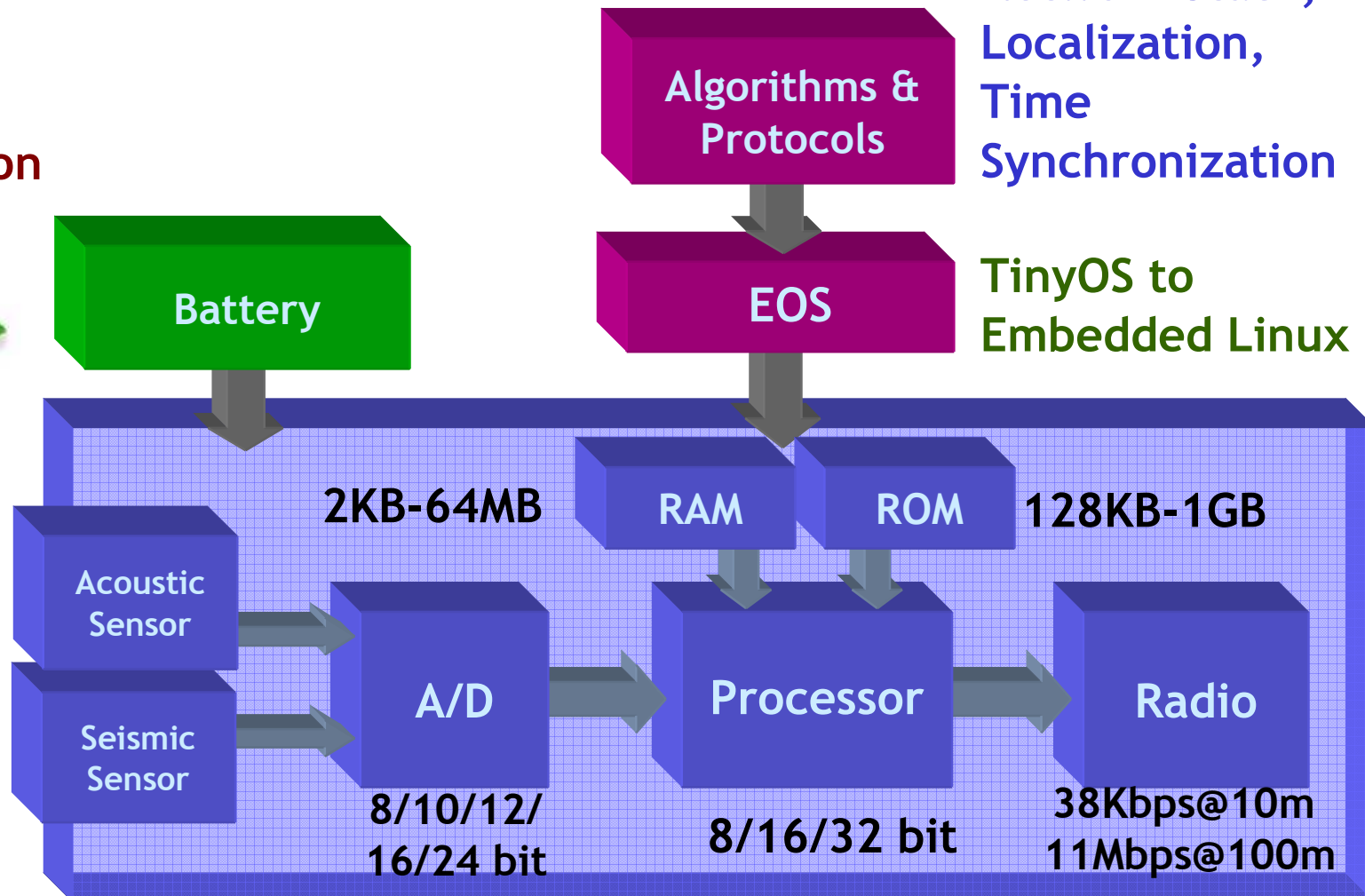
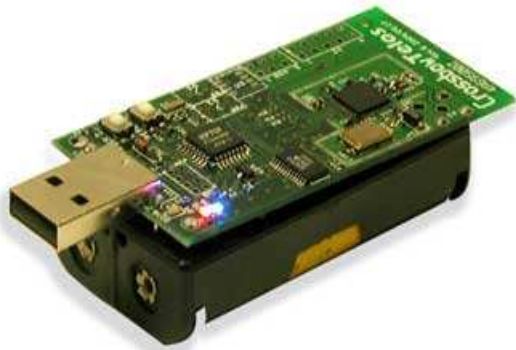
SPEC 5/03



- ✓ **Processing**
- ✓ **Sensing**
- ✓ **Communication**

Network Stack,  
Localization,  
Time  
Synchronization

TinyOS to  
Embedded Linux

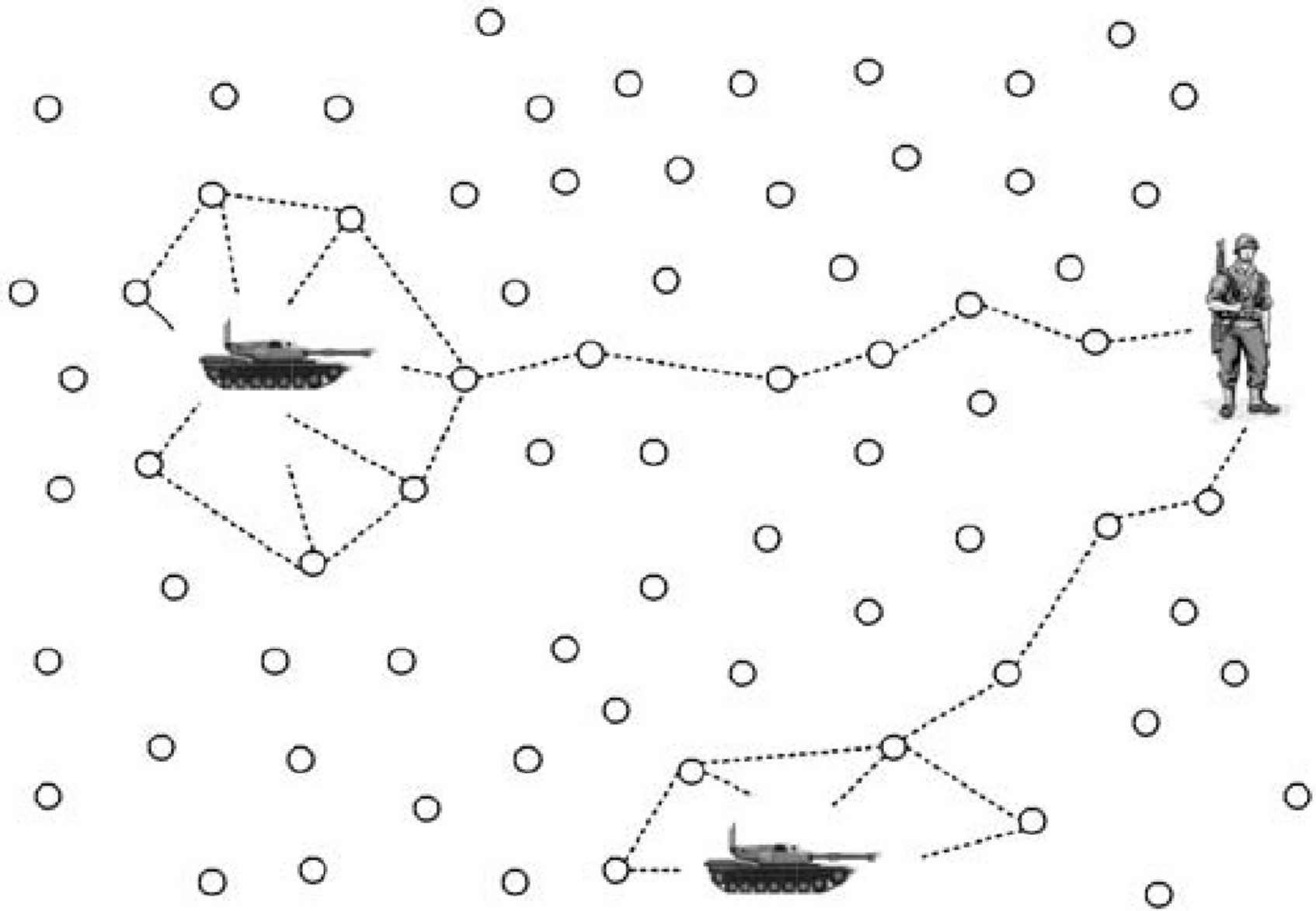


# Comparisons of 2.4GHz Motes

| Feature           | Imote2    | SunSpot | TelosB | Iris                | Description                                |
|-------------------|-----------|---------|--------|---------------------|--|
| RAM               | 32MB      | 512KB   | 10KB   | 8KB                 | Data memory for running applications       |
| CPU Frequency     | 13-400Mhz | 180MHz  | 1-8MHz | 1-8MHz              | Processing speed during active mode        |
| Program Flash     | 32MB      | 4MB     | 48KB   | 128KB               | Program memory flash for code storage      |
| Internal Flash    | "         | "       |        | 4KB                 | Nonvolatile memory for configuration       |
| External Flash    | "         | "       | 1024KB | 512KB               | Nonvolatile memory for logging             |
| Sleep Current     | 500uA     | 32uA    | 9uA    | 4uA                 | Ultra-low power operation limit            |
| Minimum Voltage   | 2.8V      | 3.0V    | 1.8V   | 1.8V                | Ultra-low power operation limit            |
| UART Primary      | X         | X       | X      | X                   | Primary data bus                           |
| UART Secondary    | 2x        |         | X      | X                   | Secondary data bus                         |
| Dedicated SPI     | 2x        |         |        | X                   | Dedicated SPI bus beyond radio connection. |
| Dedicated I2C     | X         |         |        | X                   | Dedicated sensor bus .                     |
| USB Interface     | X         | X       | X      | MIB520 <sub>±</sub> | Programming / Data interface               |
| Sensor Interface  | 100+pin   | 20-pin  | 16-pin | 51-pin              | Expansion interface                        |
| Radio Power       | 0 dBm     | 0 dBm   | 0 dBm  | 3 dBm               | Maximum output power of radio              |
| Radio Sensitivity | -95dBm    | -95dBm  | -95dBm | -101dBm             | Minimum signal strength heard by radio     |
| Radio Range       | 300 ft    | 300 ft  | 300 ft | 1000 ft             | Maximum radio range                        |

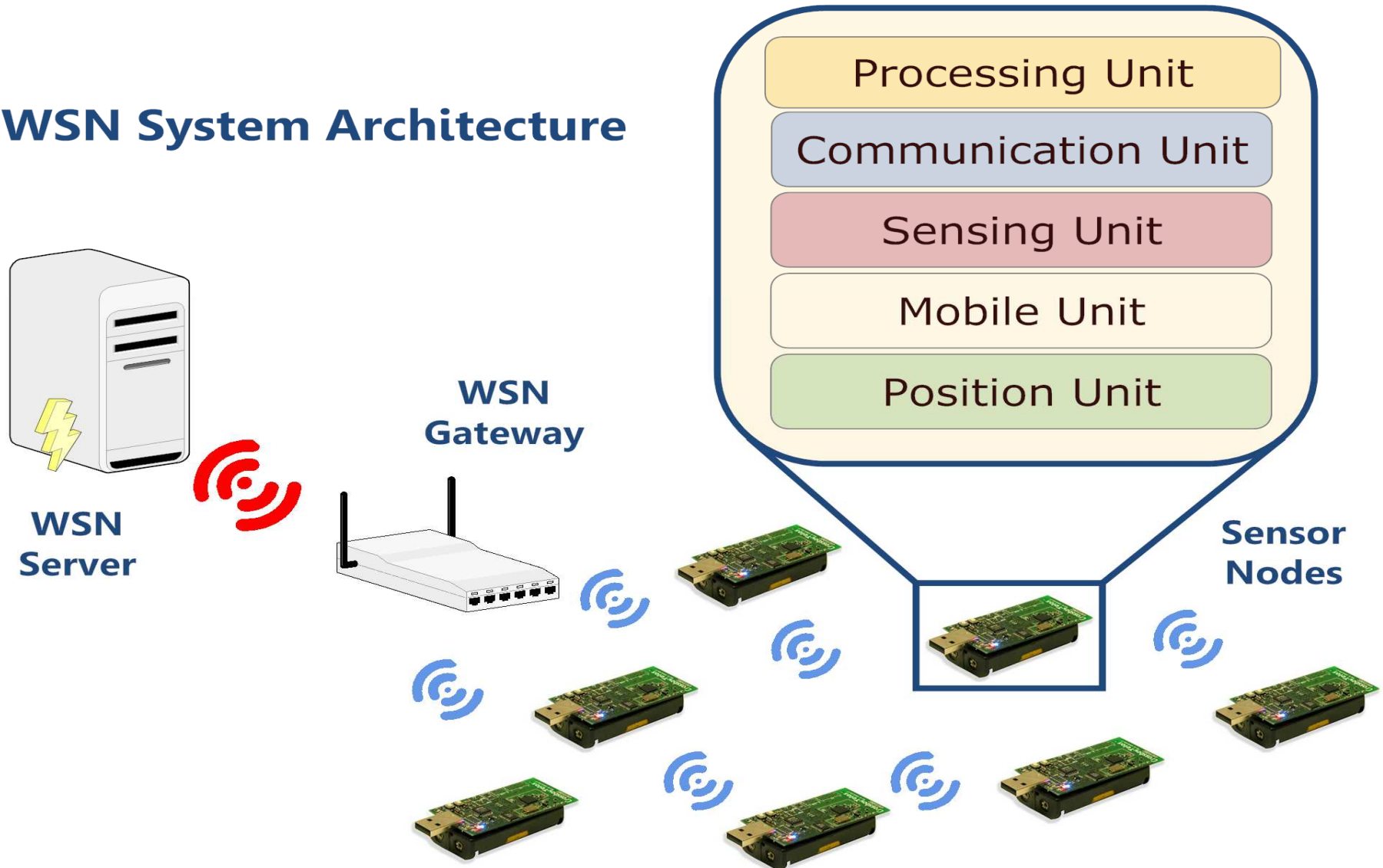
Source: Crossbow Technology (2008)

# WSN Example Application

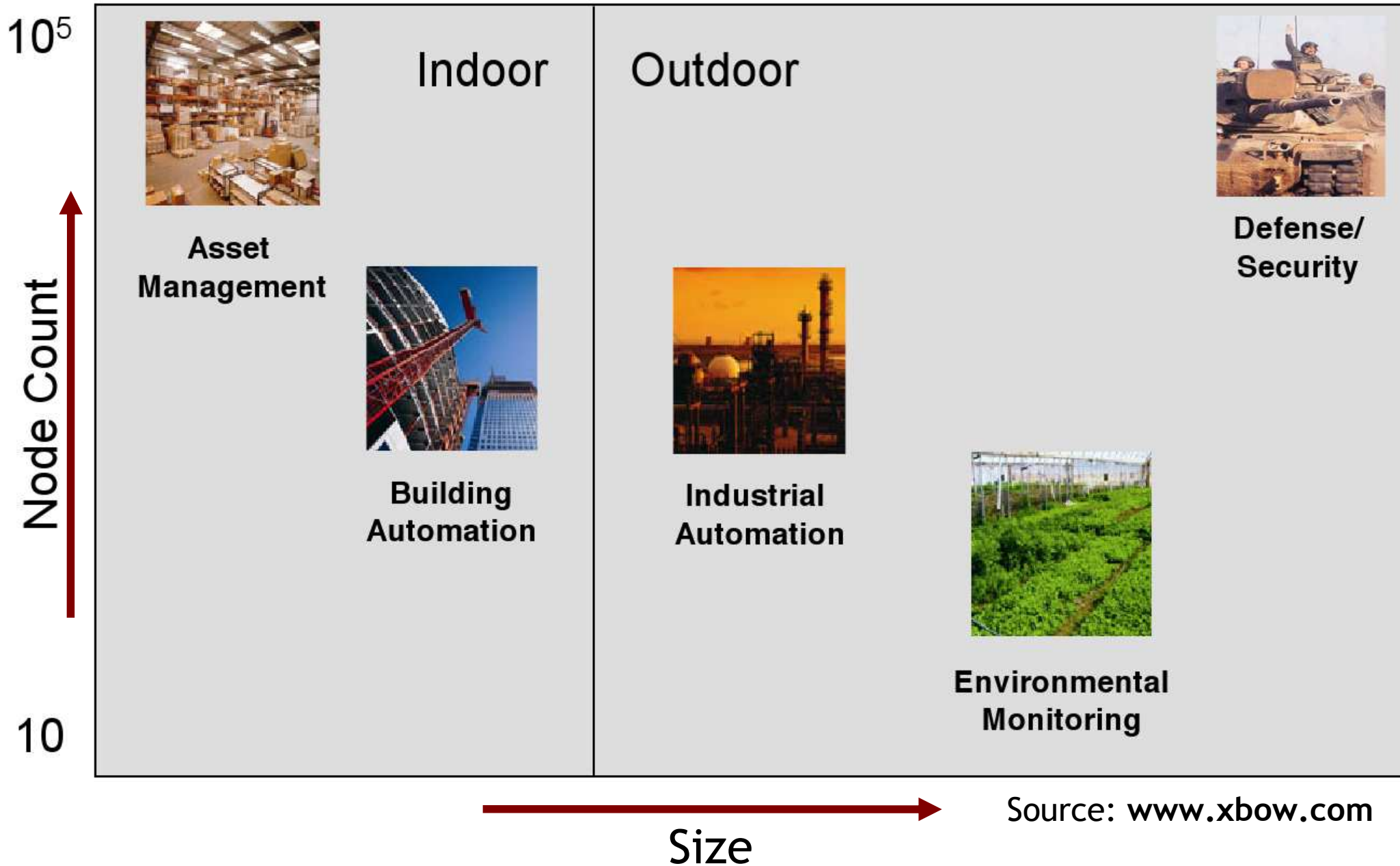


# Generic System Architecture

## WSN System Architecture



# Applications



# WSN: Killer Features



- Spatio-Temporal Accuracy
- Ease of Deployment
- Redundancy => Robustness (Node Failures)  
[Data Centric]
- Collaborative
- Smaller Size
- Fault Tolerance Communication
- Node Mobility

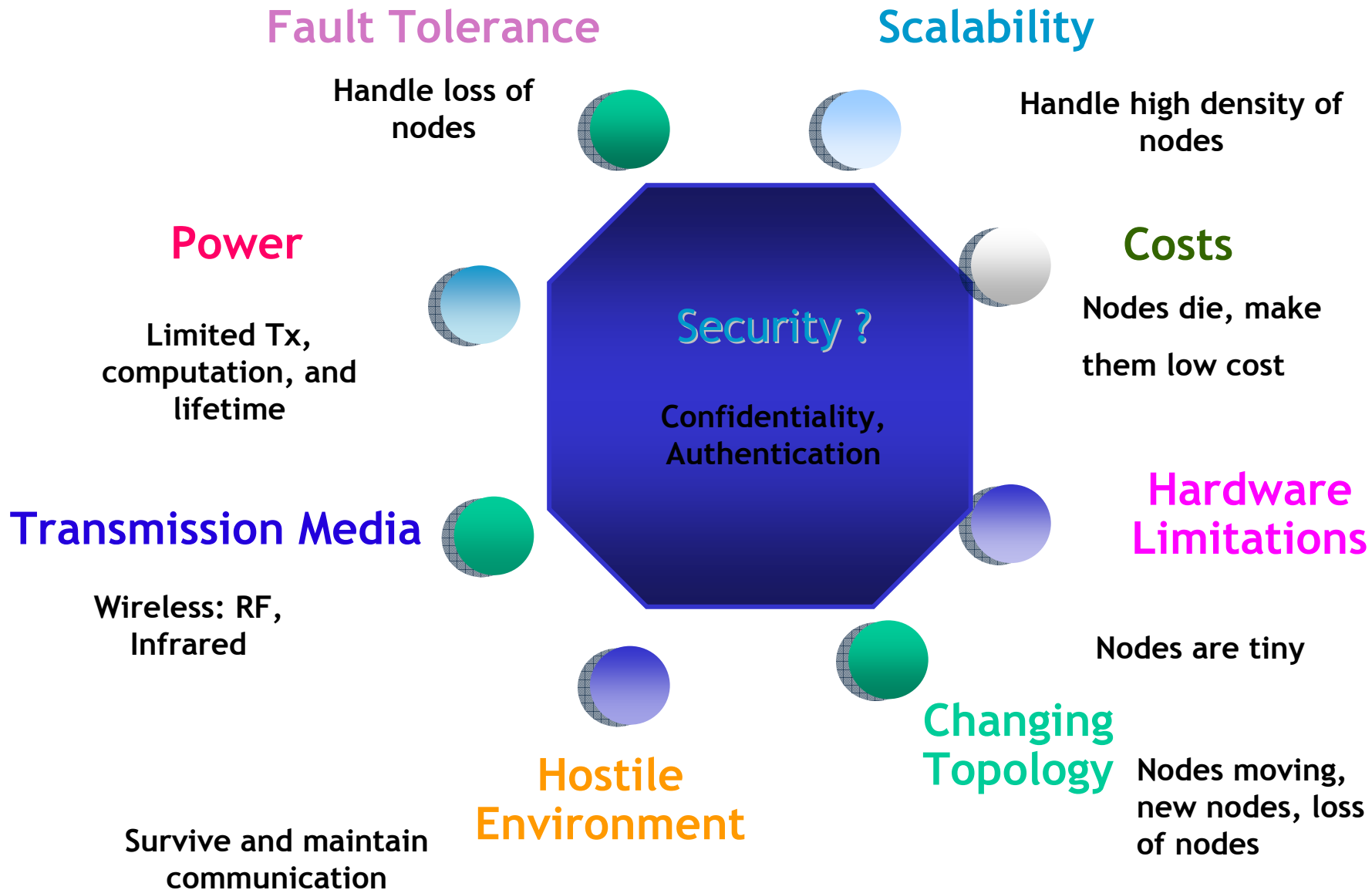
Low End Processors

Low Bandwidth Communication

Battery Powered Node

Application Driven Sensing Modalities

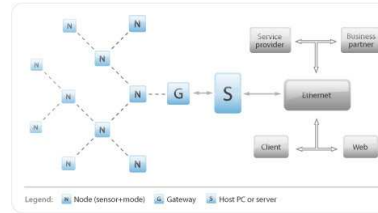
# Constraints for Wireless Sensor Networks



# Typical WSN Application Services

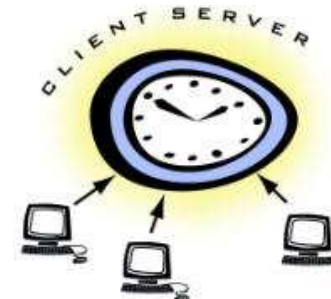
- **Network Communications**

- Reverse Multicasting
- Dissemination



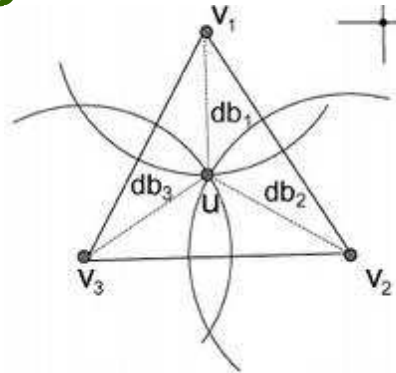
- **Time Synchronization**

- Sleep and Wake Time Scheduling
- Event Timestamping



- **Localization**

- Spatial Information
- Routing



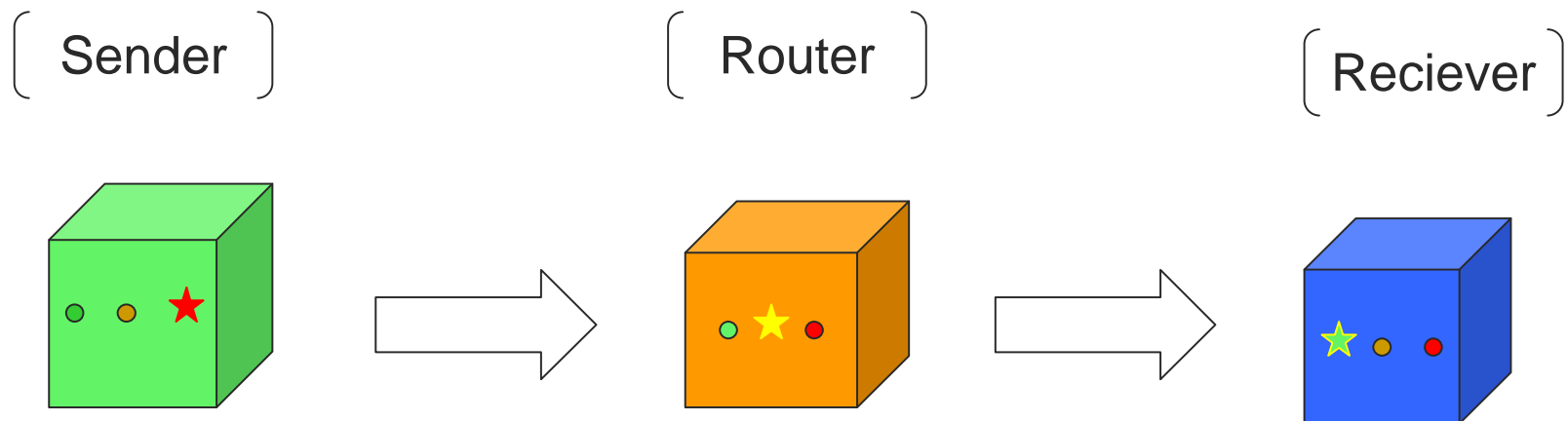
- **Security**

- Confidentiality
- Message Authentication



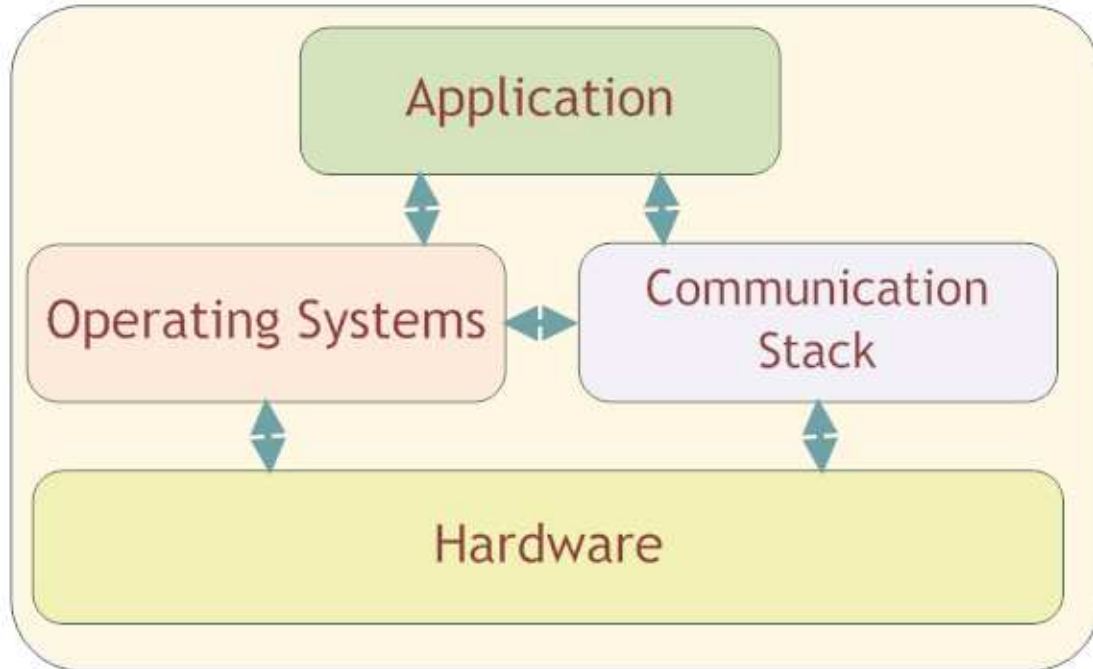
# Routing

- MultiHop
- Reverse Multicast
- Expedited by Sinks and Sensor Nodes

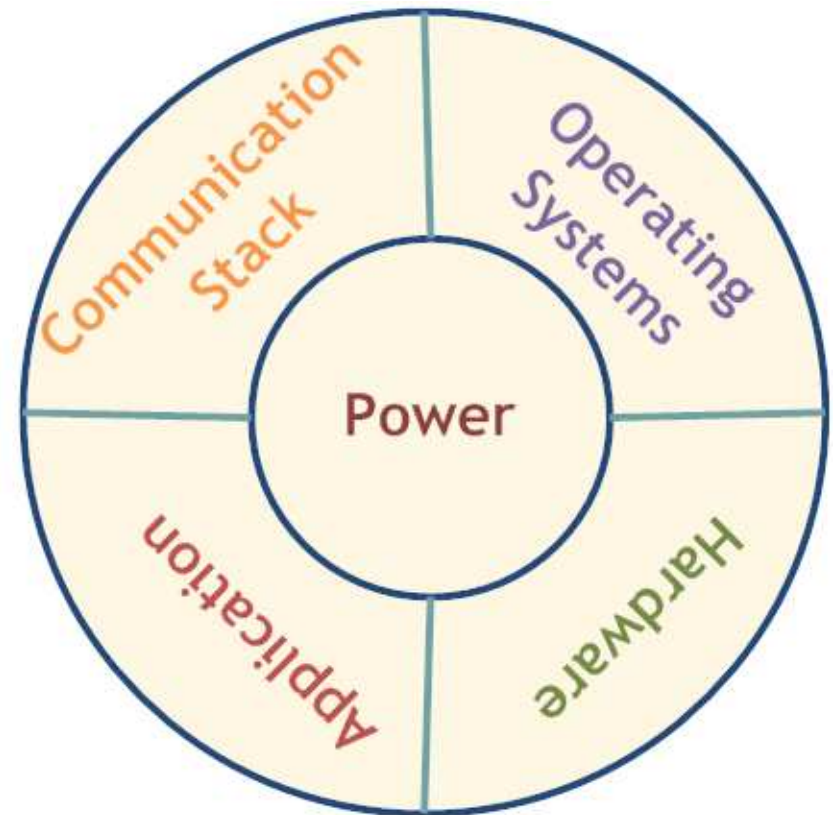


# Cross Layer Melting

Good Design  
Abstraction  
and  
Debugging



Good energy  
Efficiency &  
performance  
and less overhead



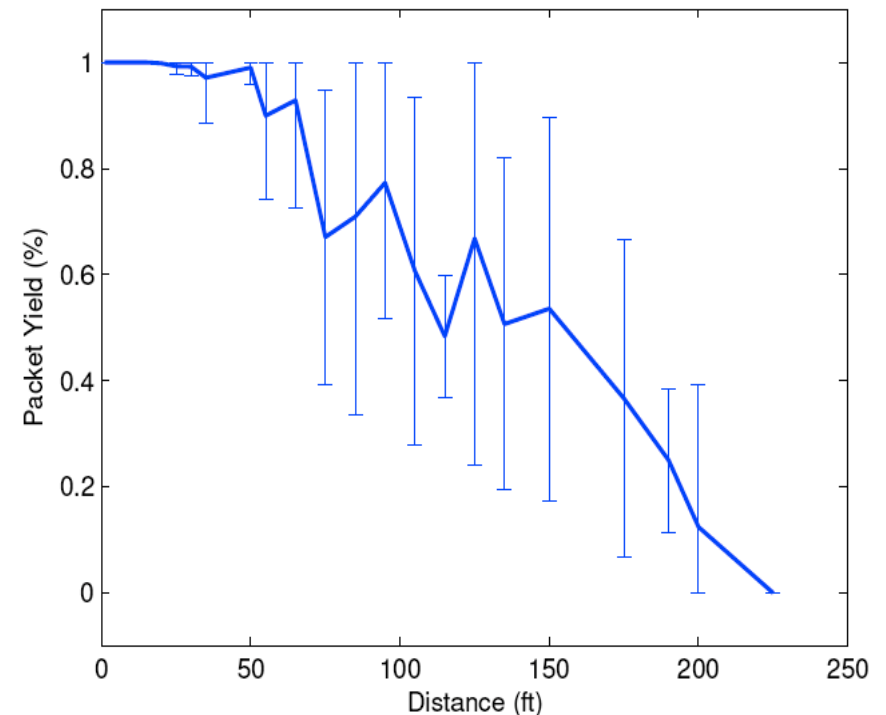
# Pragmatic Considerations

## Reliability Improvement Techniques

- Radio's Transmission area are never circular
- Coverage Areas are non-contiguous
- All radio's do not have equal range
- Symmetry (If I can hear you, you can hear me) does not exist

Existence of asymmetries requires careful identification of “good neighbors”

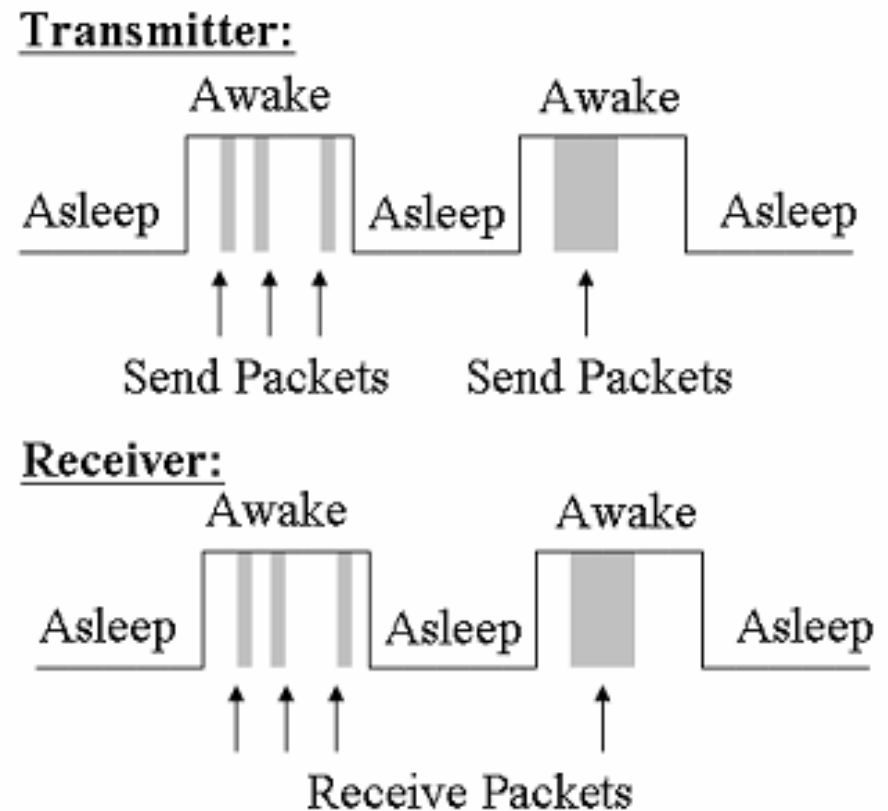
- MultiRoute to Sink
- Dynamic Route Updates
- Link Level message Acks
- End-to-End message Acks
- Automatic Retries



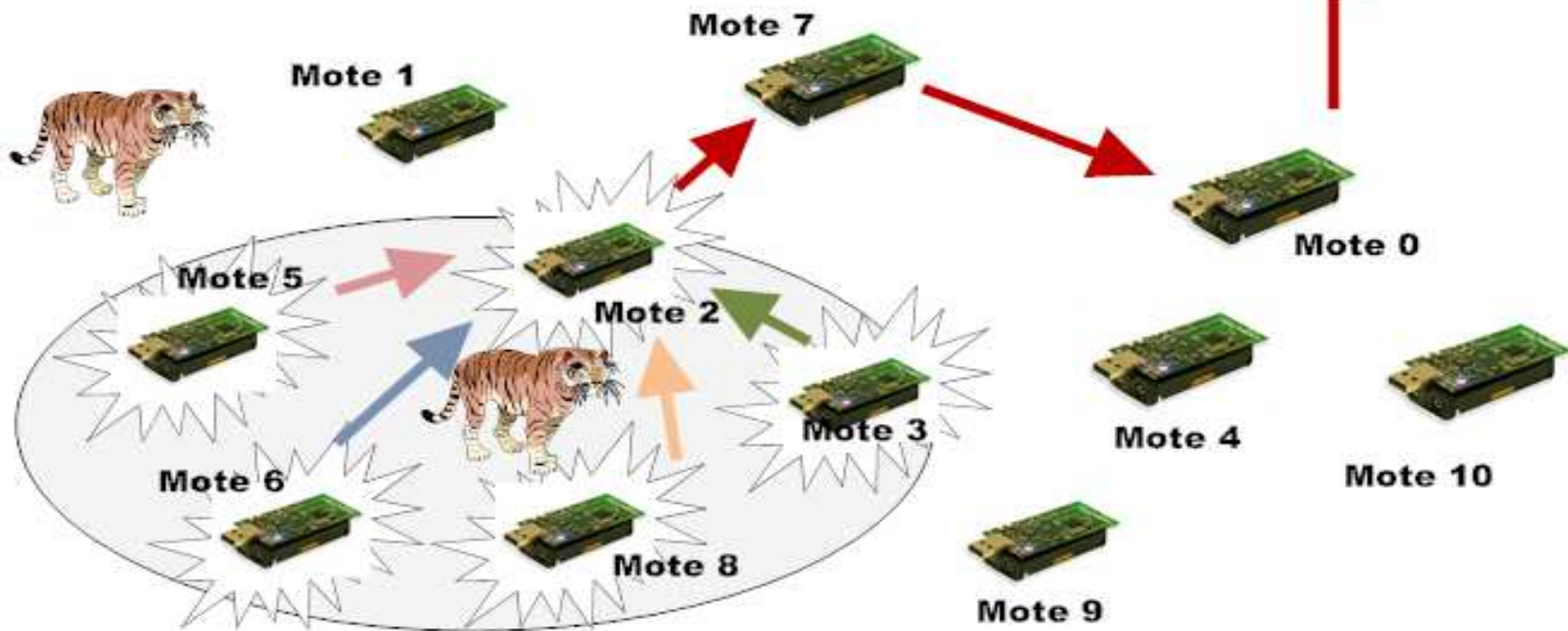
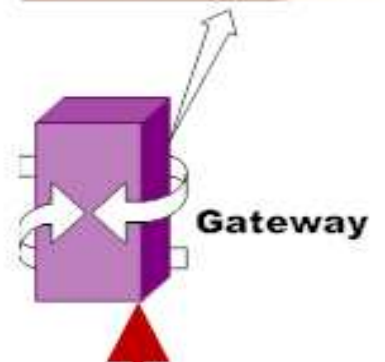
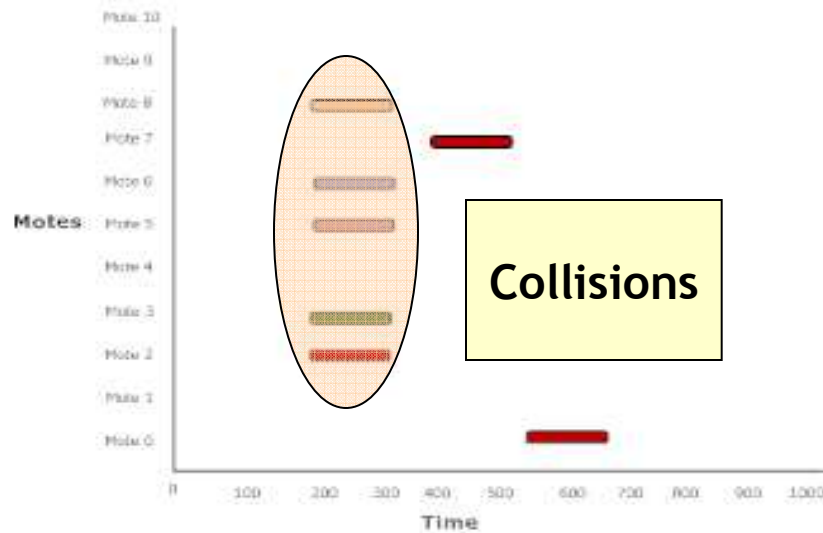
# Time Synchronization

- **Services**

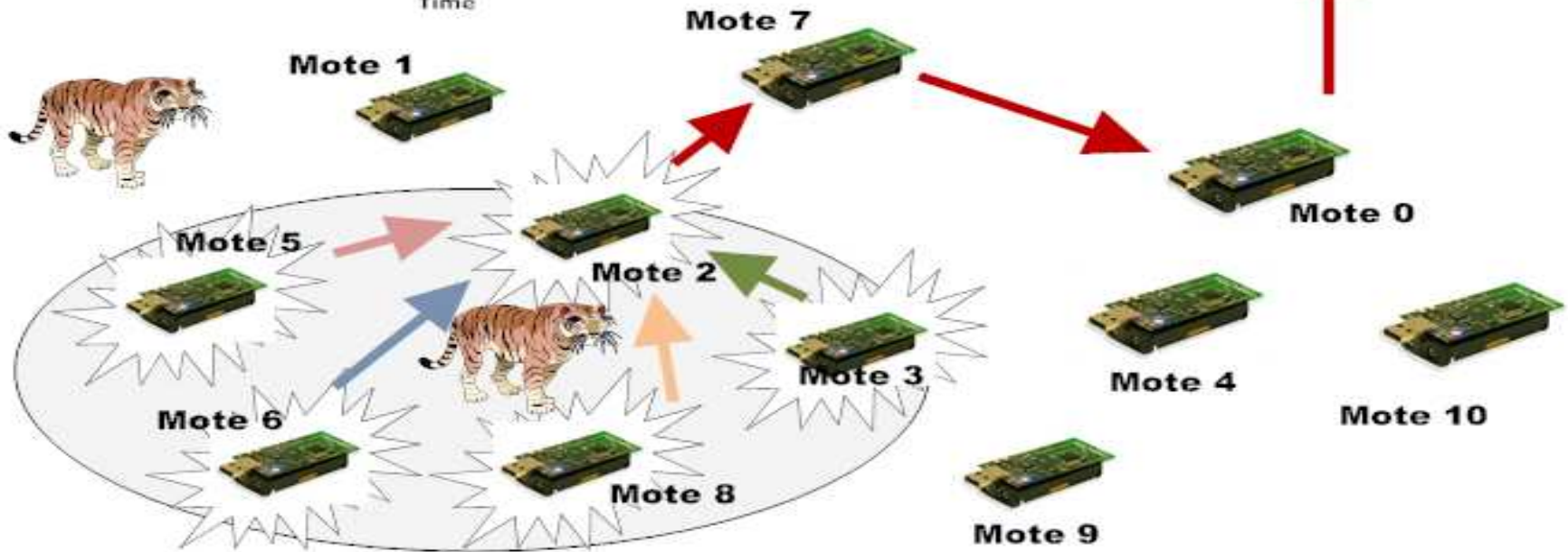
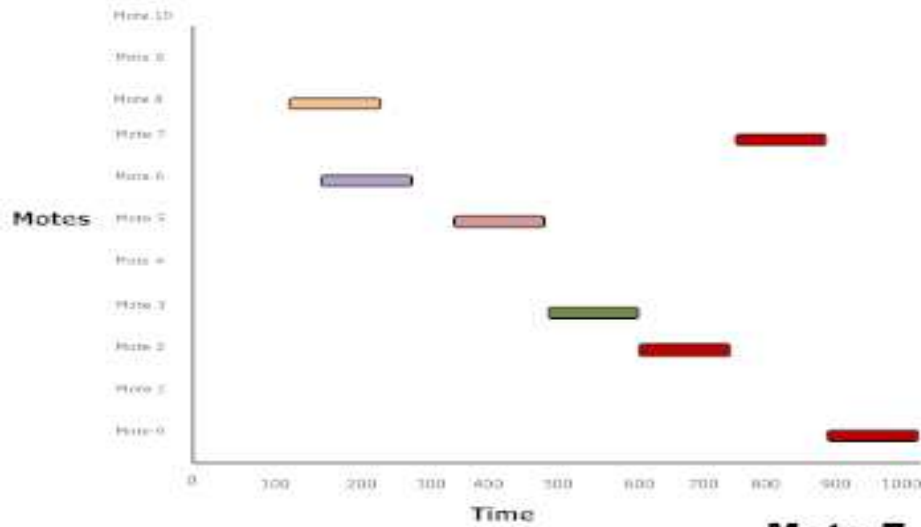
- Coordination
- Communication
- Security
- Power management
- Distributed logging
- Sensor data fusion
- Coordinated actuation
- Power-efficient duty cycling



# Time Synchronization & In-Network Processing



# Time Synchronization & In-Network Processing

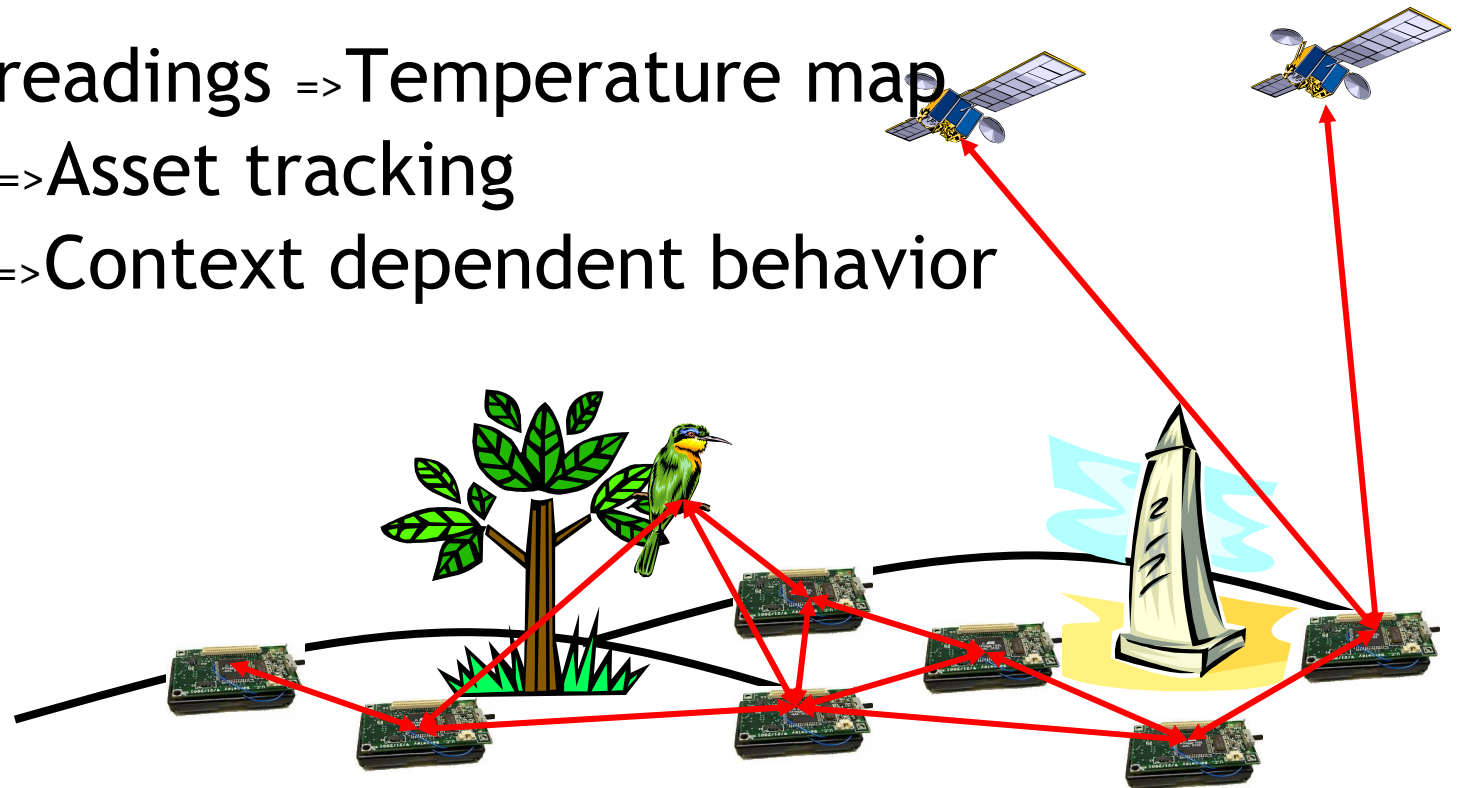


# Localization

A mechanism for discovering spatial relationships between objects

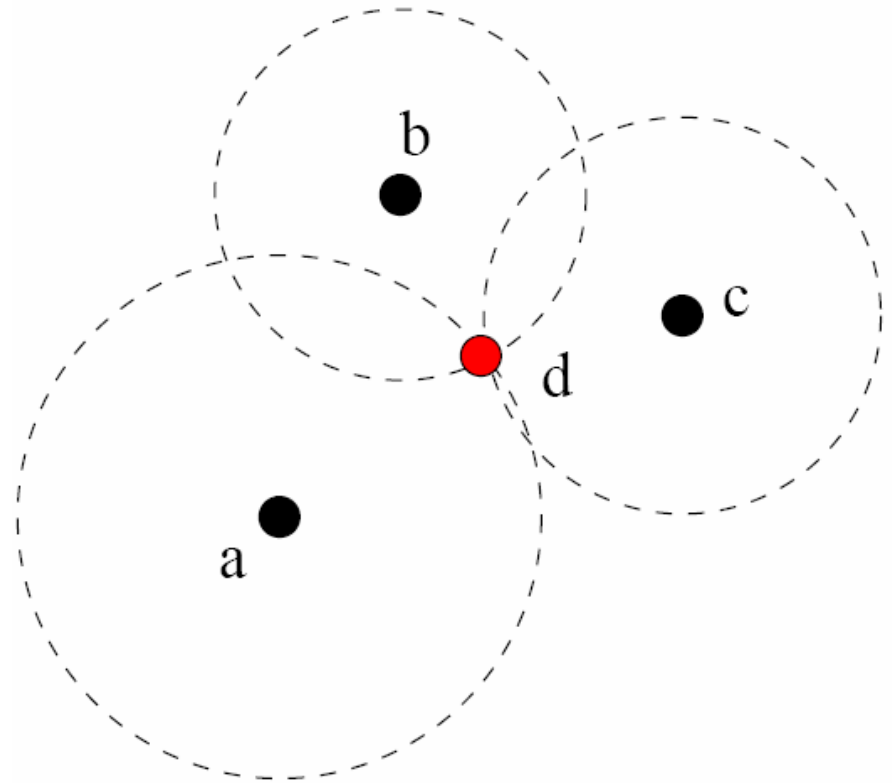
Localization gives raw sensor readings a physical context

- Temperature readings => Temperature map
- Asset tagging => Asset tracking
- Smart spaces => Context dependent behavior



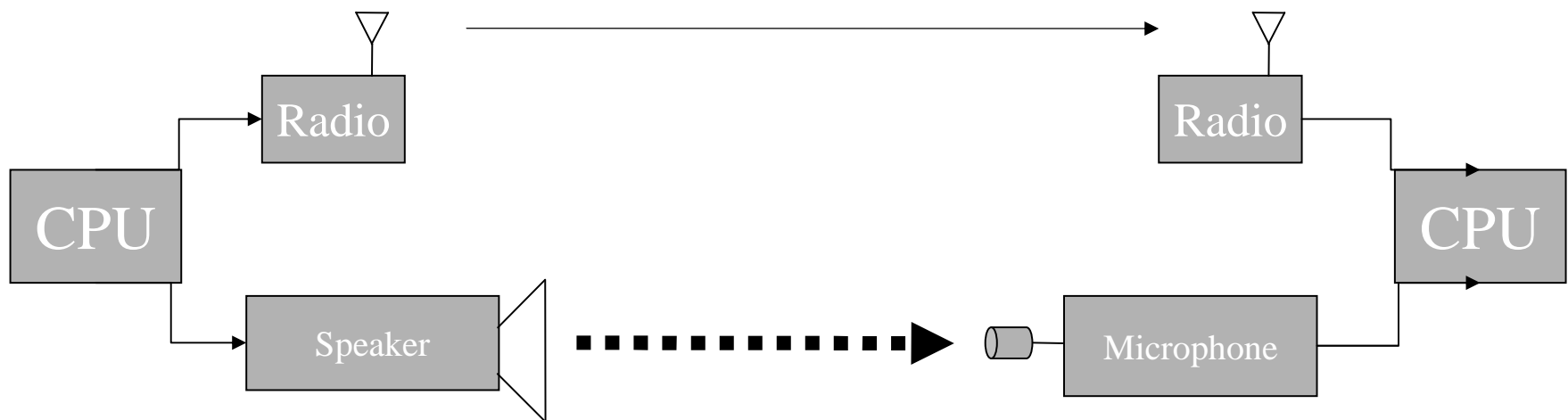
# Triangulation, Trilateration

- Anchors advertise their coordinates & transmit a reference signal
- Other nodes use the reference signal to **estimate** distances anchor nodes.



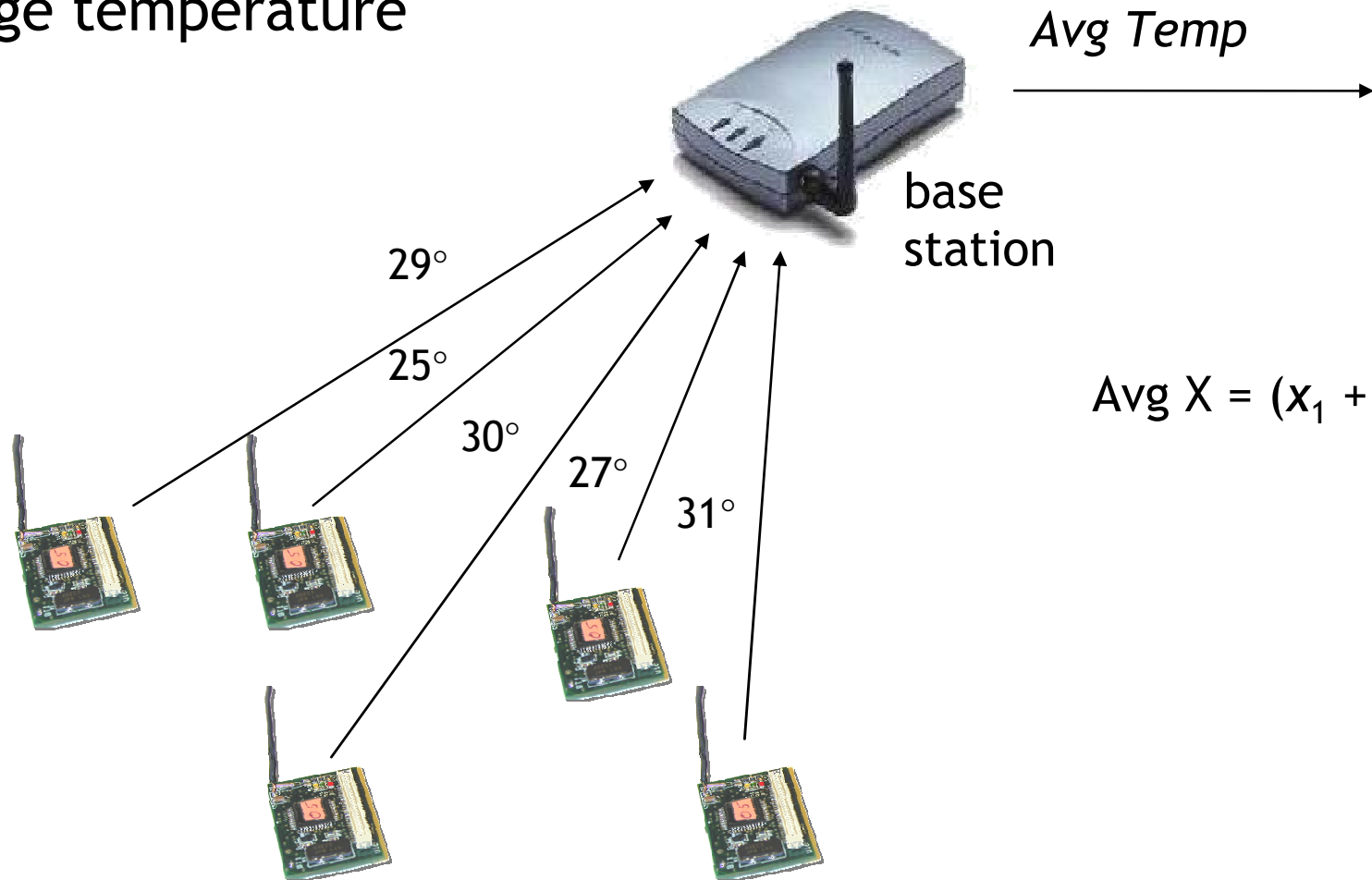
# Typical Time-of-Flight AR System

- Radio channel is used to synchronize the sender and receiver (or use a timesync service)
- Coded acoustic signal is emitted at the sender and detected at the emitter. TOF determined by comparing arrival of RF and acoustic signals



# Security

Computing the  
average temperature



$$\text{Avg } X = (x_1 + \dots + x_n) / n$$

# References

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- P. Juang, H. Oki, Y. Wang, M. Martonosi, L. S. Peh, and D. Rubenstein. Energy-Efficient Computing for Wildlife Tracking: Design Tradeoffs and Early Experiences with ZebraNet. In *Proc. ASPLOS X*, San Jose, USA, October 2002
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# Thank You



Fig 1. General structure of the proposed system.