Wireless Sensor Networks:
A Real Melting Pot

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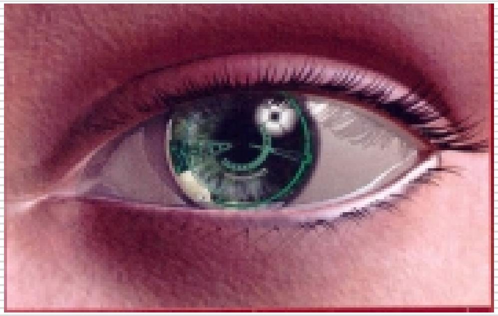


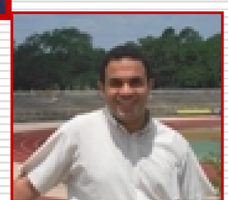
The Team

- Sherine

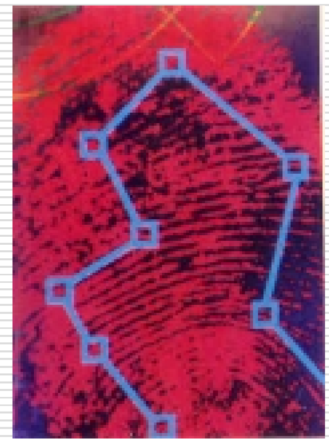
- Soumik

- Ruth

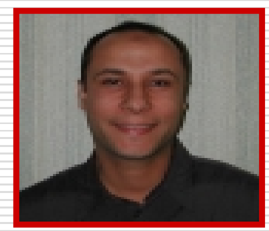
- Ahmed



- Mitune



Ashok



Shaheen

Sensors are the CORE for:

- Wearable Computers
- Embedded Computing
- Ubiquitous Computing
- Perception Systems
- They are the interface of the digital world to the real world

Hot News:

- Wall Street Journal, Feb. 28, 2007:

"*Monitoring your heart, wireless, via the Internet*"

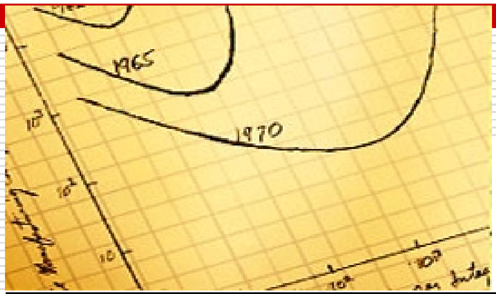
Implanted device (sensors) inside the heart; *the Chronicle* from Medtronic Inc. Send all information wireless to the network.

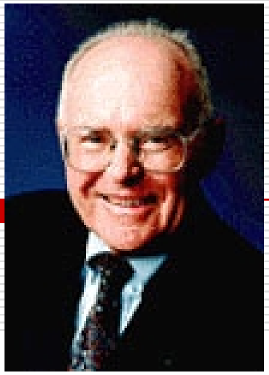
Wireless Sensors Networs:

- Evolution in Computer Architectures
- Advances in Communication Networks
- Modern Circuit Design
- Advances in Devices
- New Design Paradigms

Technology is everywhere

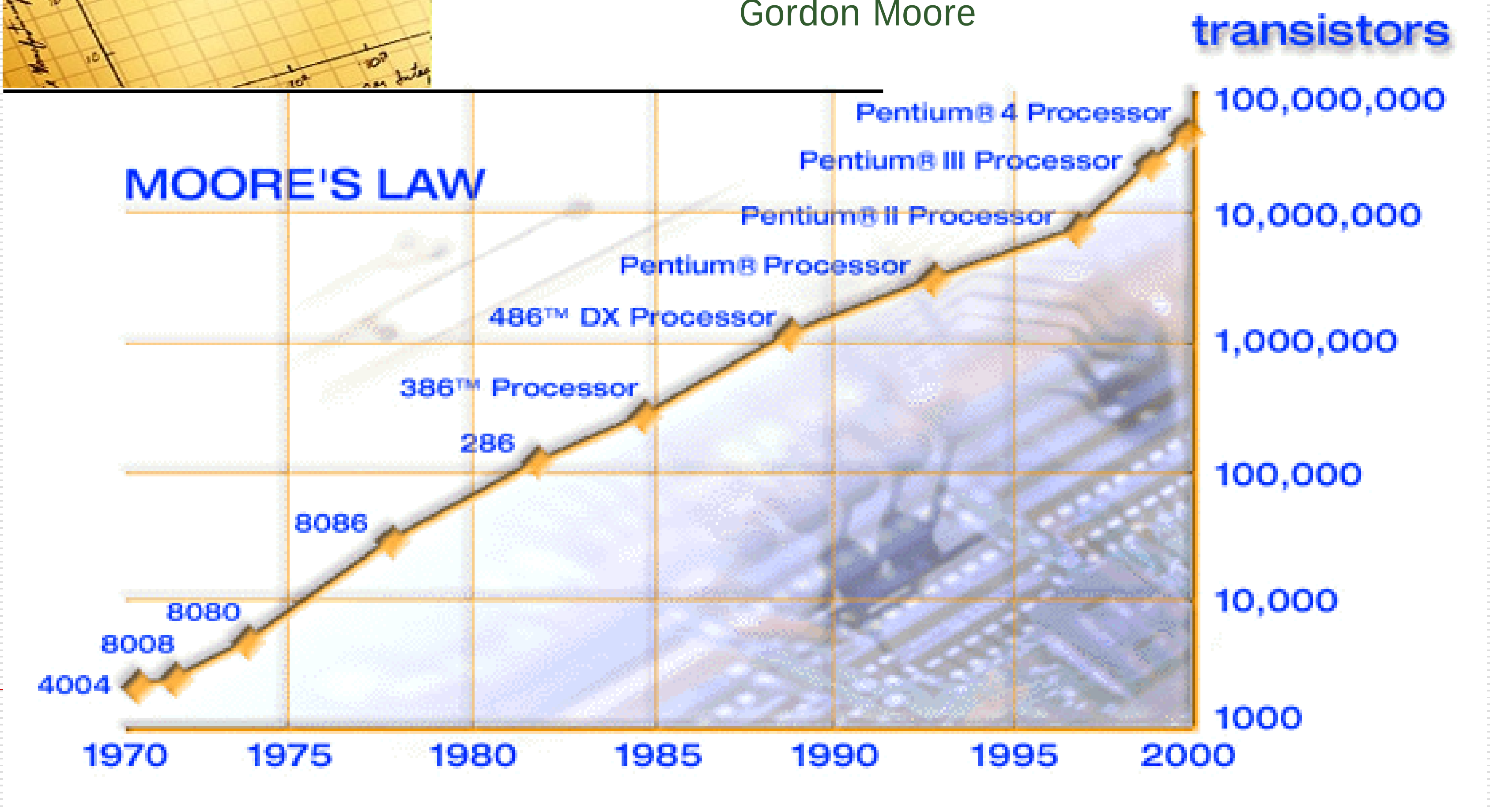
Moore’ s Law





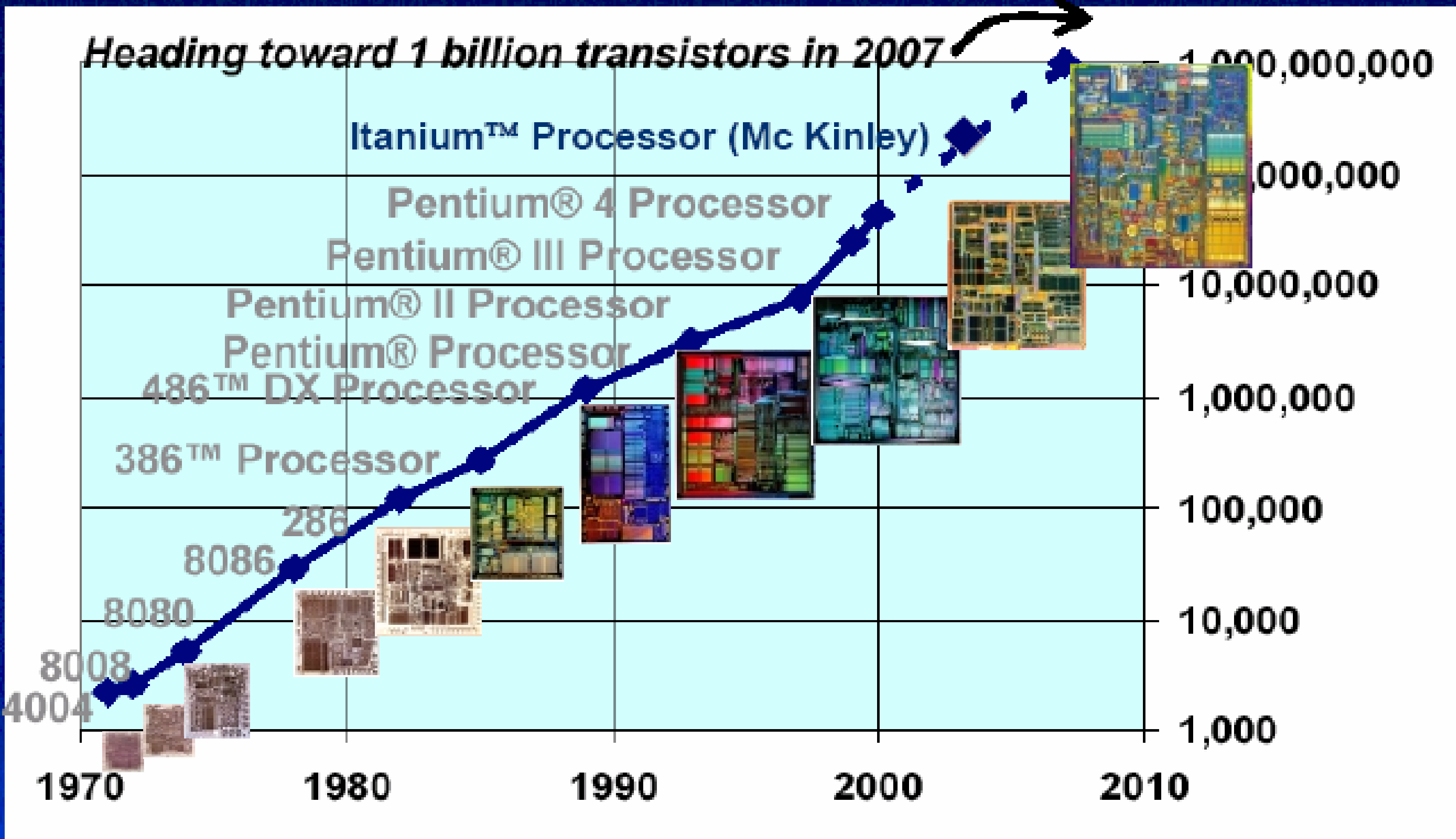
Gordon Moore

The number of transistors will double every 18 months



Moore's Law Continues

Transistors doubling every 2 years toward the billion-transistor microprocessor



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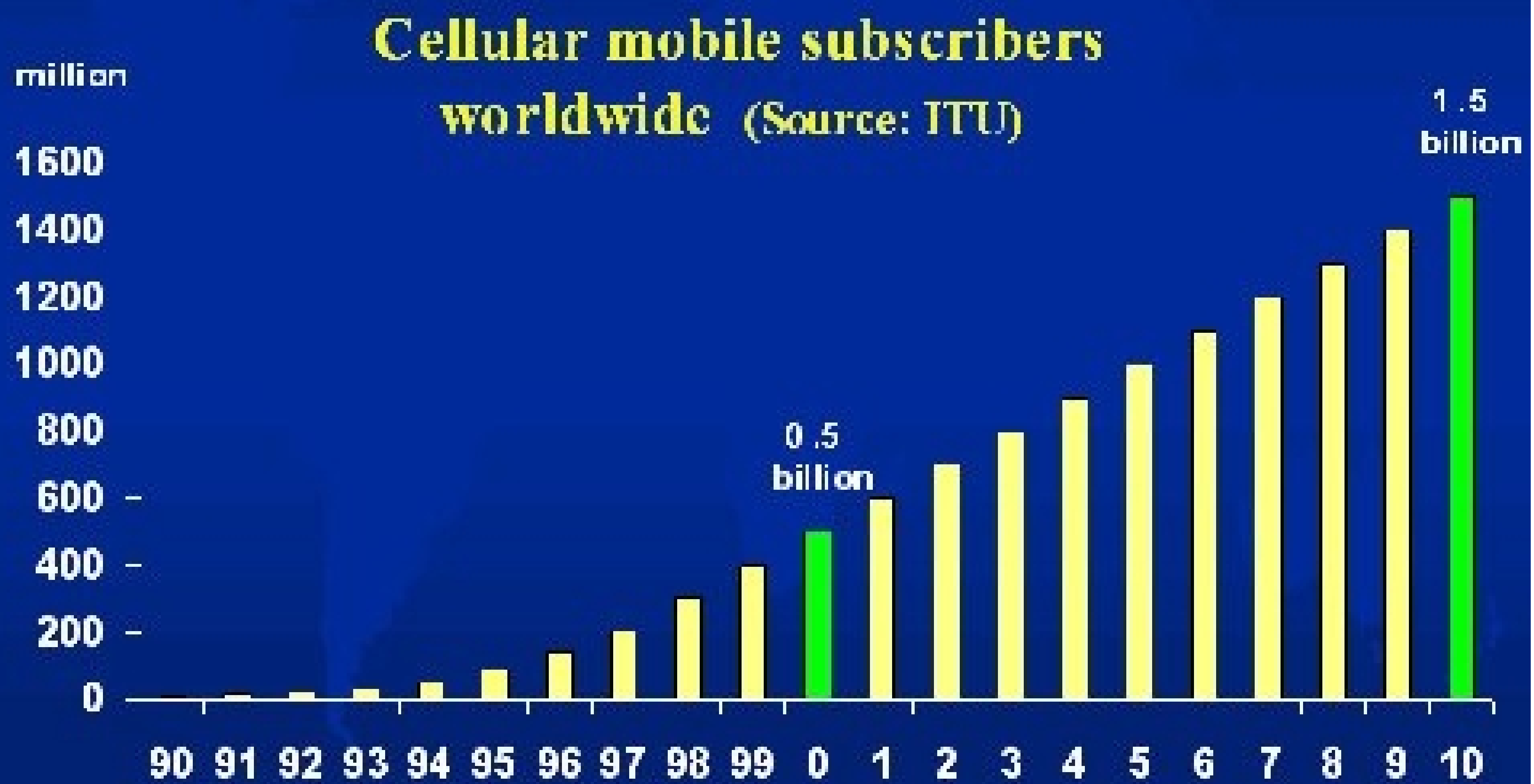
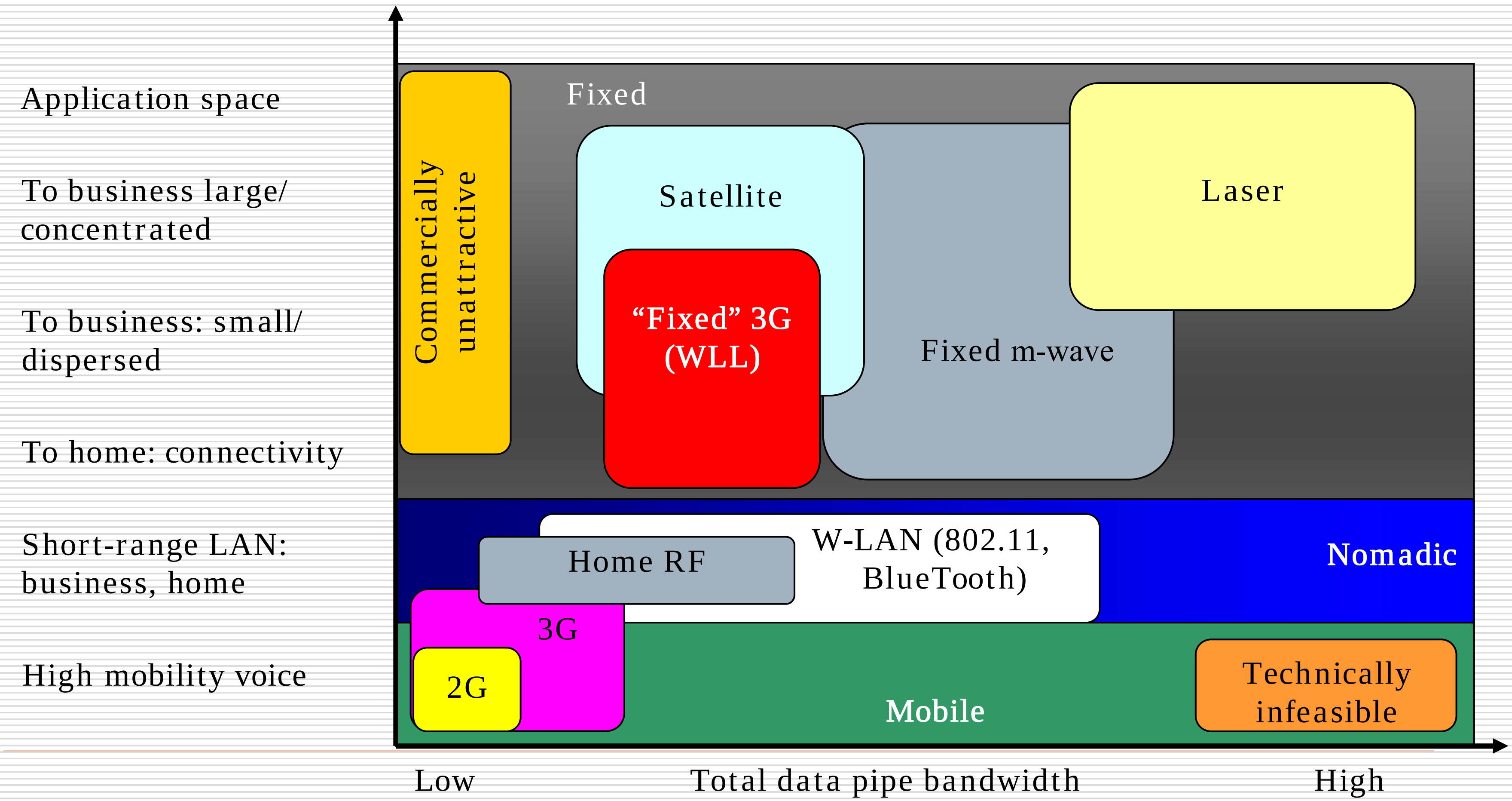
Source: Intel

Growth of cellular market



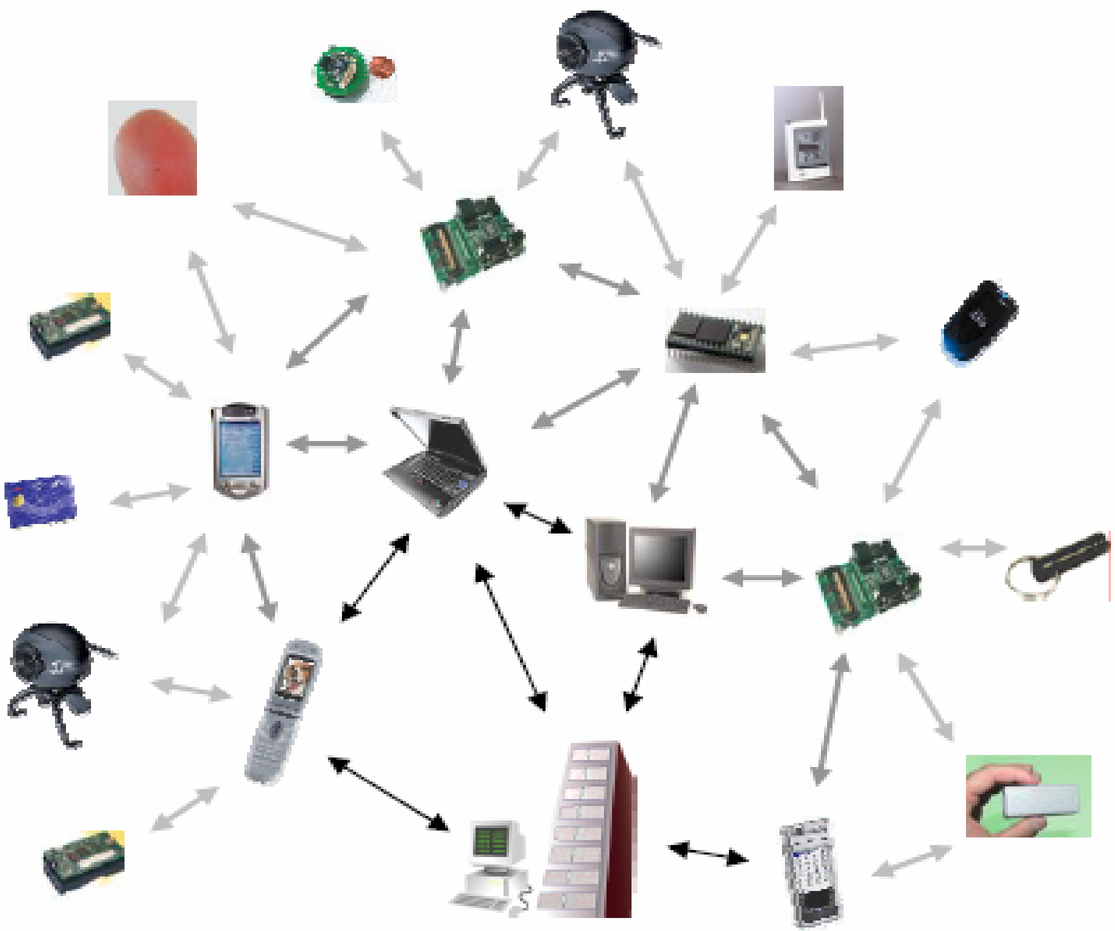
Wireless World



Examples – Research Groups

- U. of California – Berkeley
- UCLA
- Cornell
- USC
- U. of Louisiana
- MIT

Blurring the boundary between the digital and physical worlds



As these devices proliferate, we must

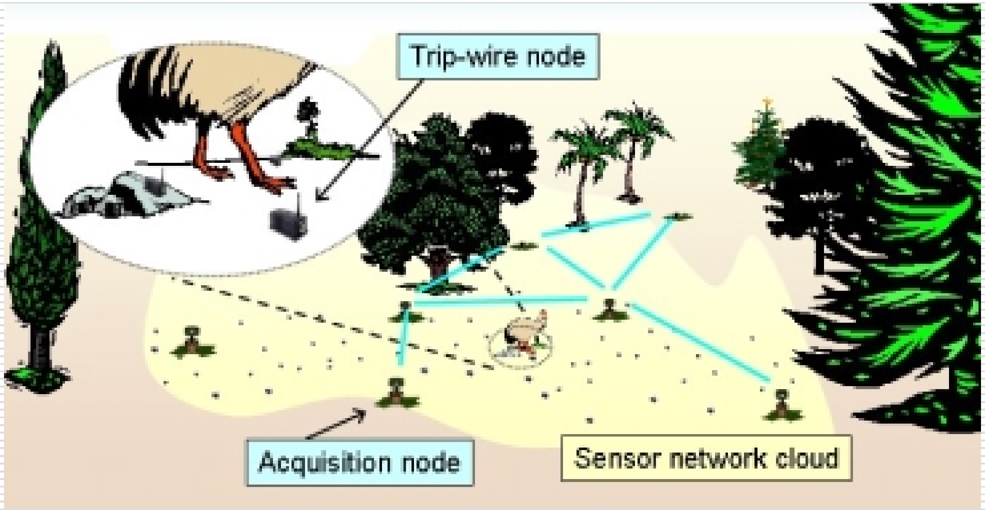
- –Deal with uncertainties in both systems and environments
- –Move from "building unreliable systems from reliable parts"to "building reliable systems from unreliable parts"

Why Wireless Network?

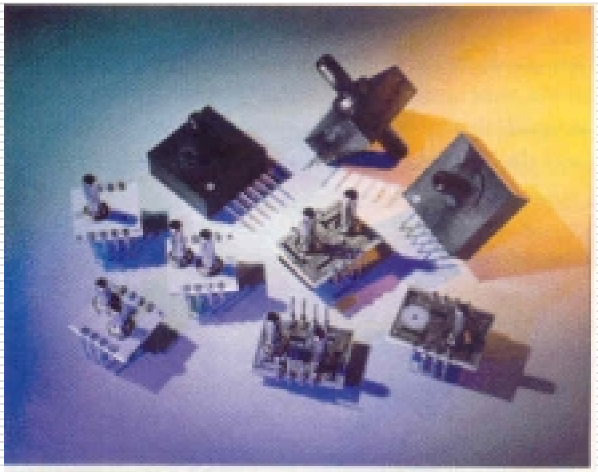
- Wireless is now cheaper to install, it will be 10% of the cost of the wired system by 2010.
- Rapid deployment.
- Wire crack or fail->high maintenance.
- Flexibility in placement.
- Connectors are expensive and not reliable.

What is Wireless Sensor Network

- Network that are formed when a set of small untied sensor devices that are deployed in an ad hoc fashion cooperate on sensing a physical phenomenon



Characteristics



- Sensor network protocols and algorithm must posses self-organizing capabilities.
- Cooperative effort.
- The sensor must carry out simple computations and transmit only the required and partially processed data.
- The number of sensors can be a several orders of magnitude higher than the nodes in an ad hoc network.
- Sensors are densely deployed (20 nodes/m^3).

Characteristics

continued...

- **The communication is not end-to-end**. The function of the network is to report the phenomenon of interest to the observer who is not necessarily interested in (or aware of) specific sensors as another end-point of communication
- **Energy is much more limited** in sensor networks than in other wireless network since it is often impossible to recharge the batteries of sensor nodes

Six Aspects of a Sensor Network Arch.

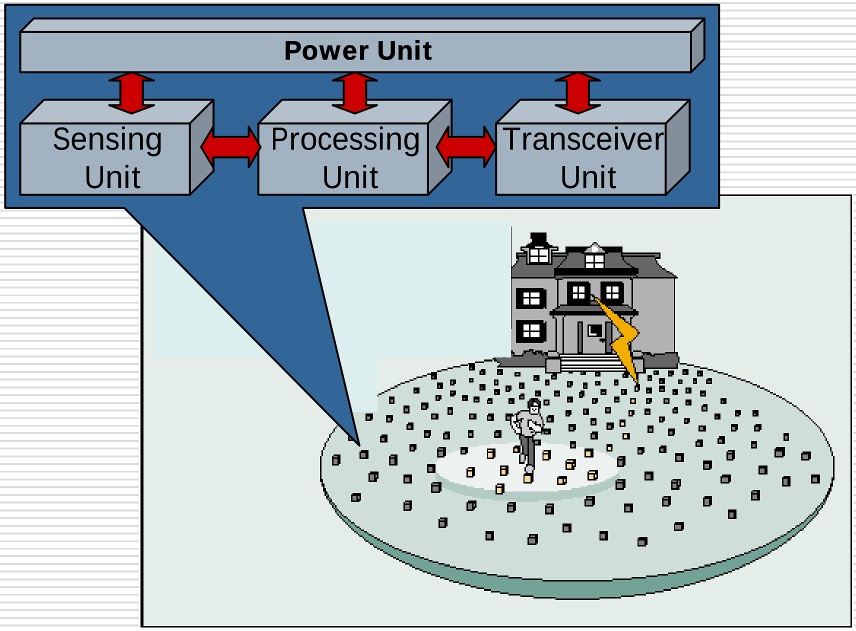
- Design Principles
  - Guidelines and constraints, what functionality, what state
  - To what are we agnostic
- Functional Architecture
  - Logical building blocks/protocols, interfaces, interconnections, interdependencies
- Programming Architecture
  - API/ISA – what logical data types and operations are expressible
- Protocol Architecture
  - Distributed algorithms to provide each component service, defn. of the information exchanged between instances
  - *Most existing work is of this form*
- System Support Architecture
  - Capabilities of the node to support the network arch.
- Physical Architecture
  - Set of nodes, interconnects, communication fabrics upon which network is constructed

Sensor Networks Requirements
(as outlined by NIST)

- Large number of sensors (stationary or Mobile) :
  Scalability is a major issue.
- Low energy use :
  The lifetime of a node may be determined by the battery life.
- Network self-organization:
  Hostile location; fault-tolerance.
- Collaborative signal processing:
  The end goal is detection /estimation of some events of interest and not just communications.
- Queering ability:
  Individual nodes may be queried.

Sensor Node

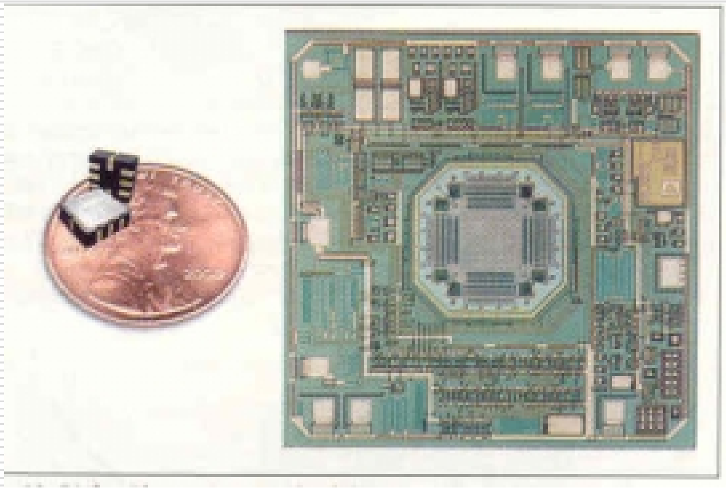
- The sensor node is made up of four basic components:
  - Sensing Unit
  - Processing Unit
  - Transceiver Unit
  - Power Unit



Sensor Node

continued...

- The sensor node must :
  - Consume extremely low power.
  - Handle its own power.
  - Low Production cost.
  - Be dispensable and autonomous.
  - Operated unattended.
  - Be adaptive to the environment.



Berkeley Motes

- Small (under 1” square) microcontroller
- It consists of:
  - Microprocessor
  - A set of sensors for temperature, light, acceleration and motion
  - A low power radio for communicating with other motes
- C compiler Inclusion
- Development ongoing

Issues governing a Sensor node Design

- Reduction of power consumption of each component in the sensor node and the network as a whole.
- Nodes must be able to perform a combination of computation, wireless communications and sensing.
- Nodes also contain a conventional battery, (preferably rechargeable) supplemented by a renewable source that generates power using scavenging techniques (vibration, solar, EM, piezoelectric, radioactive, etc..)
- Reduction of communication and communication associated energy consumption. A prudent Metric in a sufficiently dense network is the communication energy per node.

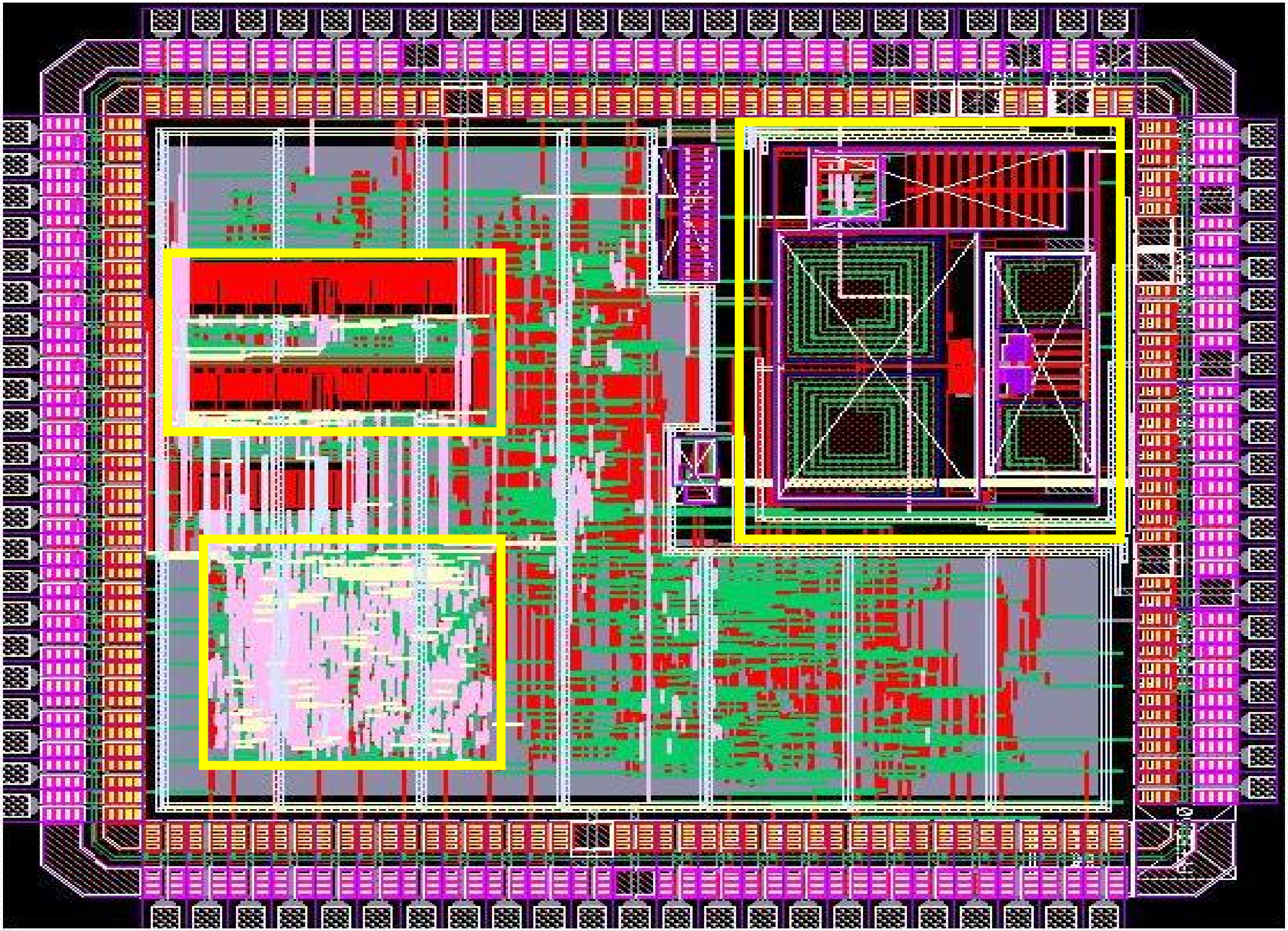
Disadvantages of current sensor network platforms

- Reliance on COTS microcontrollers that are not optimized for running event-driven applications that are mostly idle.
- Necessity of running a software layer to provide event-handling abstractions that introduces significant software overhead.
- Example : TinyOS (or similar OS) running on top of ATMEL(ATMega128), TI(MSP430) or INTEL (ARM based) microcontrollers.

Sensor Data Aggregation Processor

- First Prototype at CACS of a Processor which performs the class of computations for wireless Sensor networks called ***data-aggregation***.
- ***Aggregation applications*** are those where the desired answer depends on the sensed value at multiple nodes.
- Examples of aggregation functions are *"maximum"* and *"average"*. A user may he interested in knowing the max (or average) of a value in the WSN or in some restricted area of the WSN.
- The Processor performs *"snapshot aggregation" (*If the function needs to he performed once) and "*periodic aggregation" (*user needs an update in periodic intervals).
- Built on AMI 0.5um process. Can serially process Sensor data at a Maximum rate of 50 Mbps. Average power consumption at 50Mbps is 300mW.

Integrated Sensor Processor



Sensor Network Design Factors

1. Sensor mobility:

   Fixed; movable planned/known; random motion.

2. Number of sensors in the application domain & scalability required :

   1 to 10; 10 to 1000; 1000 to 100000; 100000+.

3. Power source & life :

   Wired; wireless on pre-existing; wireless separate supply.

4. Security :

   High; low; encryption.

Sensor Network Design Factors

continued...

5. Sensor intelligence :

   Single or multi-function; dumb; addressable- 2 way, multi-path, broadcast.

6. Actuation processes :

   Tightly coupled or separate actuator; auto or manual trigger Local, intermediate or NOC decision point.

7. Intelligence & information distribution schema :

   All to central NOC or distributed |intelligence at remote sites; secure vs. non-secure sites; level of remote data storage.

8. Level of fusion & collaboration :

   Multi sensor or multi node direct communication; query capability from sensor site, other in field, NOC.

Sensor Network Design Factors

continued...

9. "Hop" constraints :

   Internodes; to actuation; to NOC.

10. Ranges allowable & optimal :

    Internodes; to router or node sink; to secure site.

11. Communication medium :

    Wired; wireless entirety; wired to router/node sink then wireless; multi mode

Factors affecting wireless sensor network.

- Data reliability.
- Battery life.
- Cost.
- Transmission range.
- Data rate.
- Data latency.
- Physical size.
- Data security.

Ubiquitous Computing and Monitoring System (UCoMS)
for Discovery and Management of Energy Resources

Project Aims

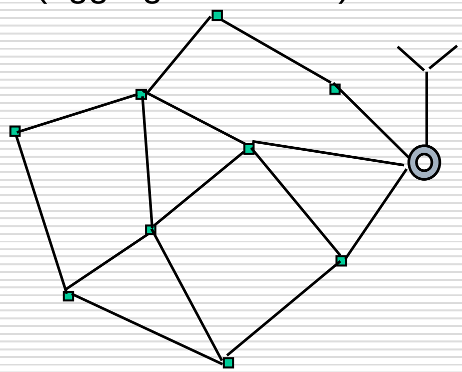
- Drilling and production data logging and storage to expand seismic databases using wireless network systems
- Massive grid computing power to support reservoir development optimization and seismic simulation
- Safety monitoring of well platforms & transport pipes
- Support of long-term platforms monitoring
- Use of decommissioned platforms as experimental testbed

UCoMS Wireless Network Prototype

Wireless Sensor Network

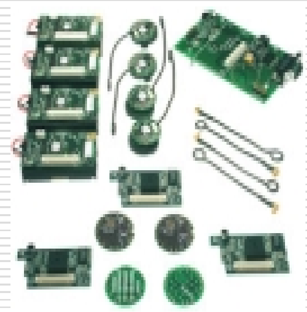
Sensor Node

Sink (aggregation node)

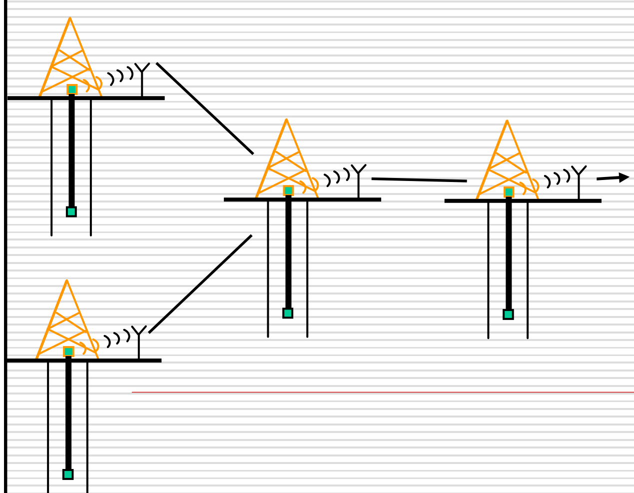


Equipment

- Smart Sensors
  - Two dozens (small-scale)
  - Sixty four (full-size)
- Eight laptops



IBW Network



Equipment

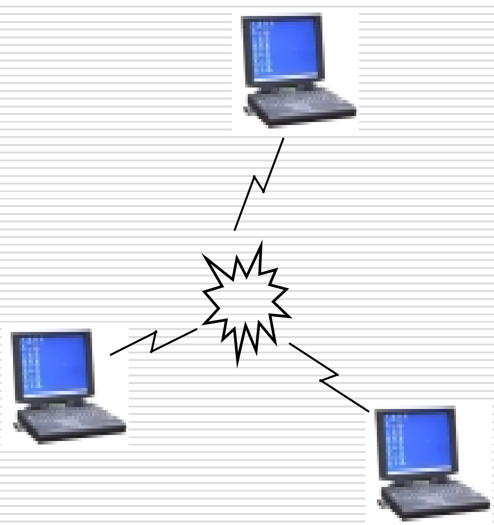
- Tsunami Wireless Ethernet Bridges
  - Four nodes (small-scale)
  - Eight nodes (full-size)
- Ten laptops

PERSONNEL

- UL Lafayette
  - 4 PIs
  - 4 Research Assistants
  - CMPS 6x9
  - CMPS 575/576
- Southern University
  - Graduate students
  - Undergraduate students

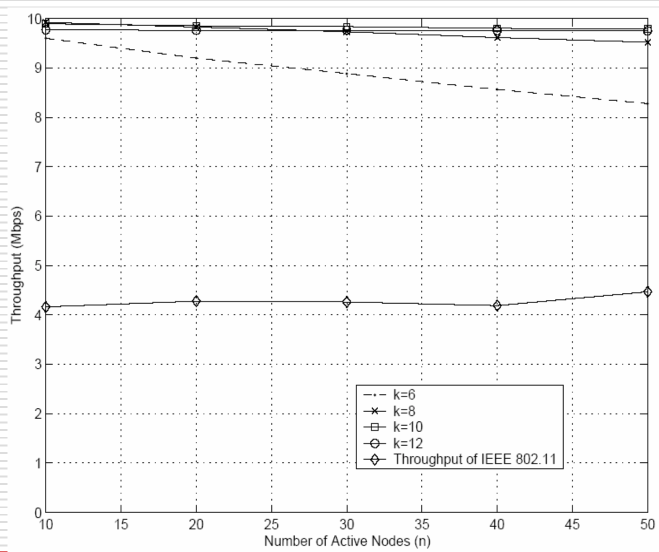
Medium Access

- **<u>Problem</u>**:
  - Congestion
  - High collision
  - Low throughout



SYN-MAC

- **<u>Objective</u>**:
  High channel efficiency
- **<u>Propose Approach</u>**:
  Binary countdown
- **<u>Preliminary Result</u>**:
  Significantly higher channel efficiency than IEEE 802.11



Unique Features

- High efficiency
- Simplicity
- Robustness
- QoS support
- Fairness
- Decentralization

Proposed Work

- Protocol design
- Implementation
- QoS support
- Eval. & fine-tune
- Prototyping

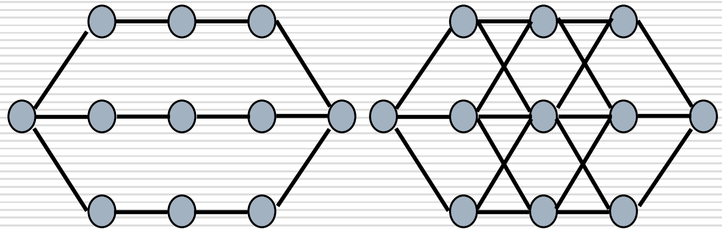
S-Path Routing

- **Problem**
  - Link failures
  - Unreliable
  - Low date rate
- **Objective**: Improve perform

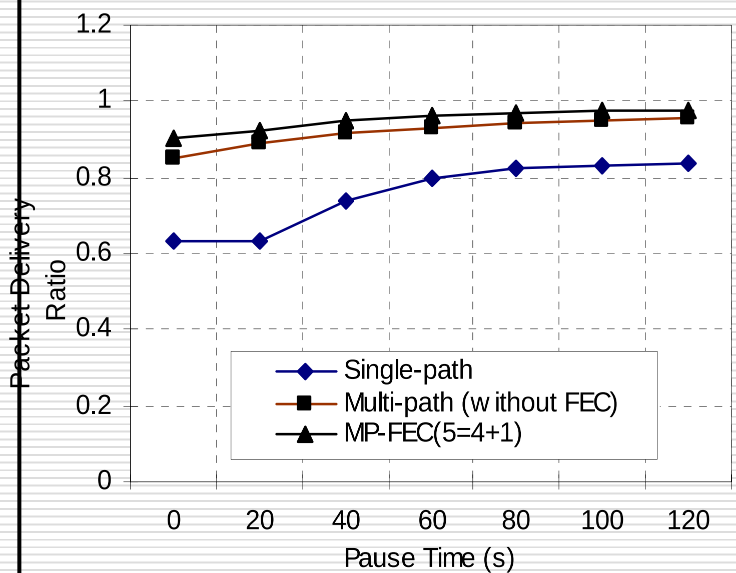
High Performance Wireless Networks

M-Path Routing

- **Using Multiple Paths**



- **Preliminary Results**



Unique Features

- High reliability
- High data rate
- Low overhead

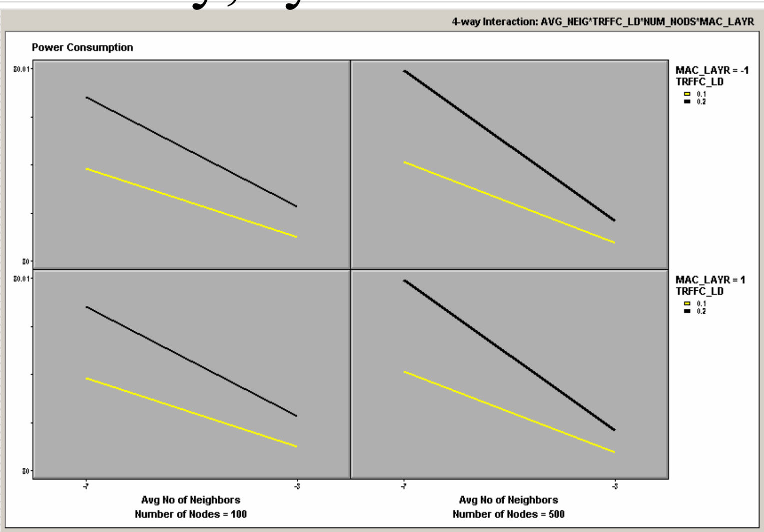
Proposed Work

- Route discovery
- Protocol design
- Implementation
- Eval. & fine-tune
- Comparison
- Prototyping

Reliable Transport	Approach: Cross-layer Based TCP	Unique Features
• **Problem**: – Distinguish causes of packet errors • **Objective**: – Improve TCP throughput	• **Use Cross-layer Model** – Link quality – Congestion – Path stability • Control TCP data rate •TCP response to packet loss	• Flexible • Adaptive • Dynamic channel and path metrics **Proposed Work** • Distributed feedback control mechanisms • Implementation • Evaluation • Comparison • Prototyping

Energy Efficiency and System Optimization

- **Problem**: cross-layer parameter and protocol interaction hinders performance
- **Objective**: improve energy efficiency, system lifetime.



Simulation results: 4-way interaction plot

Proposed Work: Modeling and Protocol Design

- Empirical data collection.
- Derive multiple factor empirical models.
- Development cross-layer architecture and protocols to minimize power consumption and increase system lifetime.