

# Wireless Sensor Network

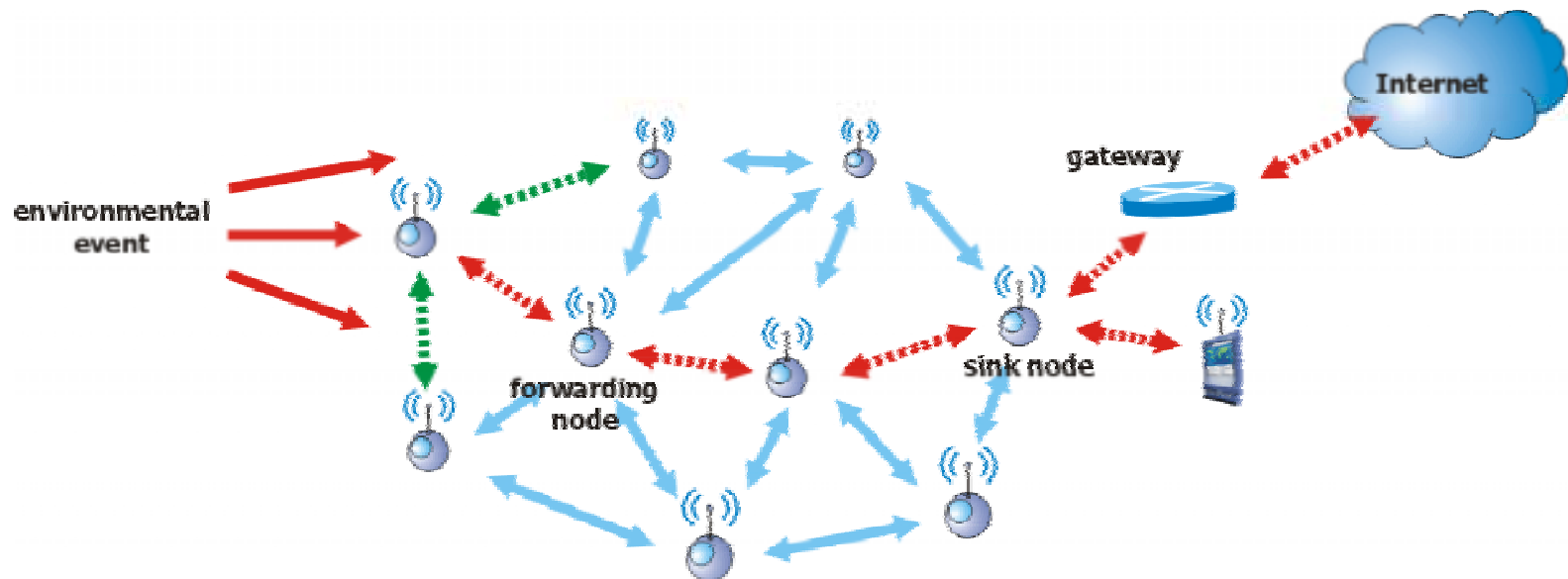
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# Background

- Advancement of integration between “tiny embedded processors, wireless interfaces, and “micro-sensors” based on MEMS led to emergence of *wireless sensor network*.
- Characterized by their ability to monitor the physical environment through ad-hoc deployment of numerous tiny, intelligent, wirelessly networked sensor nodes.

# What is Wireless Sensor Networks

- Large number of heterogeneous sensor devices
  - *Ad Hoc Network*
- complex sensor nodes with
  - communication, processing, storage capabilities



# Emerging applications

- Indoor Settings: condition based maintenance of equipment in factory
- Outdoor environment:
  - Monitor natural habitats
  - Remote ecosystems
  - Forest fires
  - Disaster sites
  - Defense armaments
  - Spy microsats

# Challenges of WSN

- Requirements: *small size, large number, tetherless and low cost*. Hence constrained by
  - Energy, computation and communication
- Small form factors => prohibits large long lasting batteries
- Cost & energy => low power processors, small radios with minimum bandwidth & small transmission ranges.
- Ad-hoc deployment => no maintenance and battery replacement
- Increase NW lifetime => No raw data to gateway for computation

# Topics to be discussed

- Simulation tools on WSN
- A simulation architecture overview
- Sensor node model & framework of SN
- Battery model
- Case studies
- Bonus points

# Existing Simulators

## **JavaSim:**

- Pros
  - Very modular
  - Easy to use
- Cons
  - Geared for wired inter-networks
  - No wireless support

## **GlomoSim:**

- Specific for mobile wireless networks.
- Built as a set of libraries. The libraries are built in Parsec( a C-based discrete event simulation language).
- Layered architecture with easy plug-in capability.

# Existing Simulators

- NS-2: De facto standard for network simulations
  - Does support wireless simulations
  - A primitive energy model is present.
  - Lots of documentation.
  - Uses Tcl to specify the Components, and Otcl to glue them together.

Cons:

- Difficult to use and learn
- Supposedly more useful for getting statistics for lower level protocols.
- Originally built for wired networks, later extended for wireless.
- Supposedly, does not work well for large topologies.

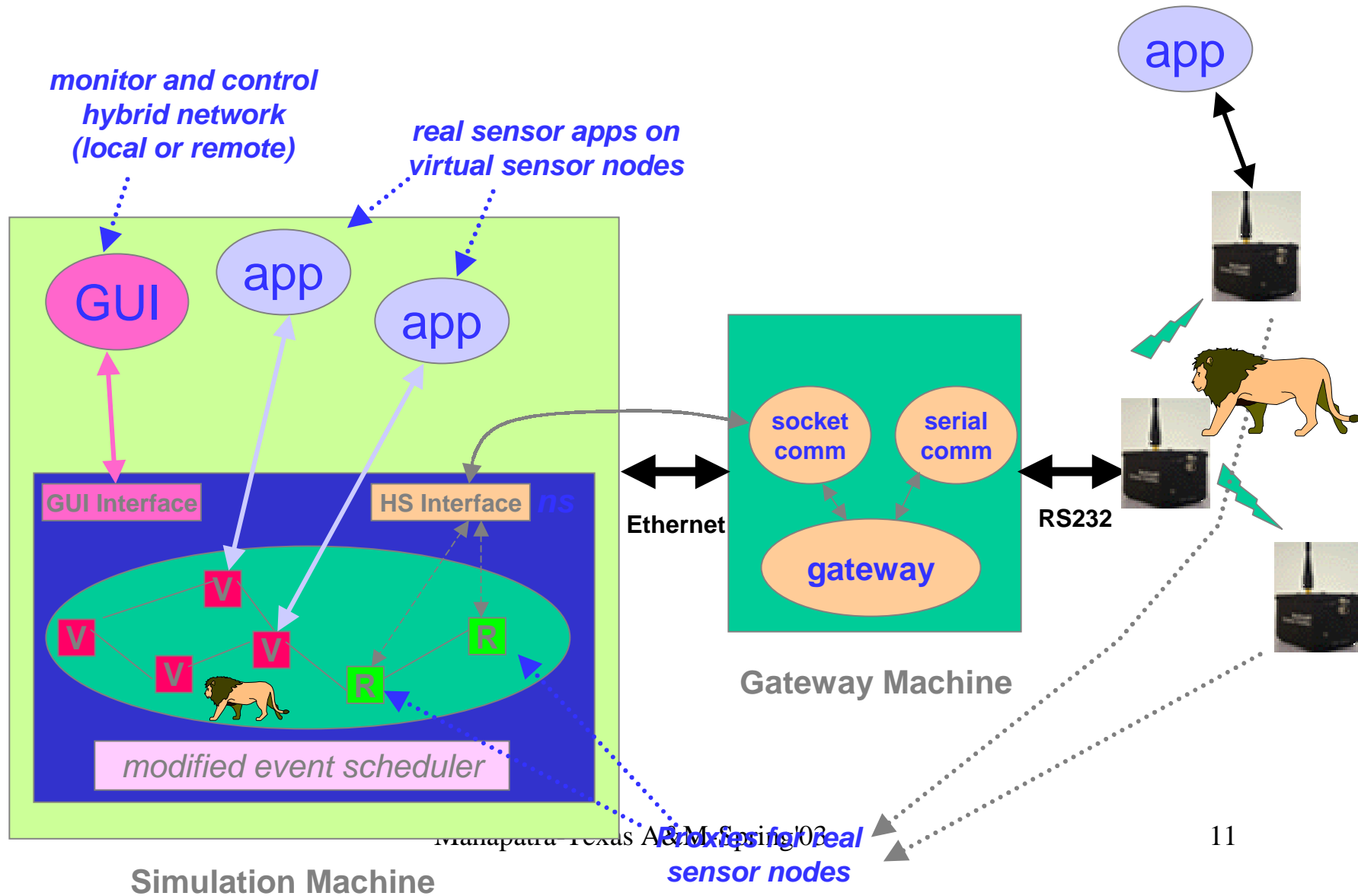
# Status of simulators

- Other simulator: OpNET
- All these tools are not equipped to capture all the aspects of interests in sensor networks.

# Current Simulator: SensorSim from UCLA

- Extension to NS - 2.
- Provides battery models, radio propagation models and sensor channel models.
- Provides a lightweight protocol stack.
- Has support for hybrid simulation.
- Must be integrated with NS - 2.

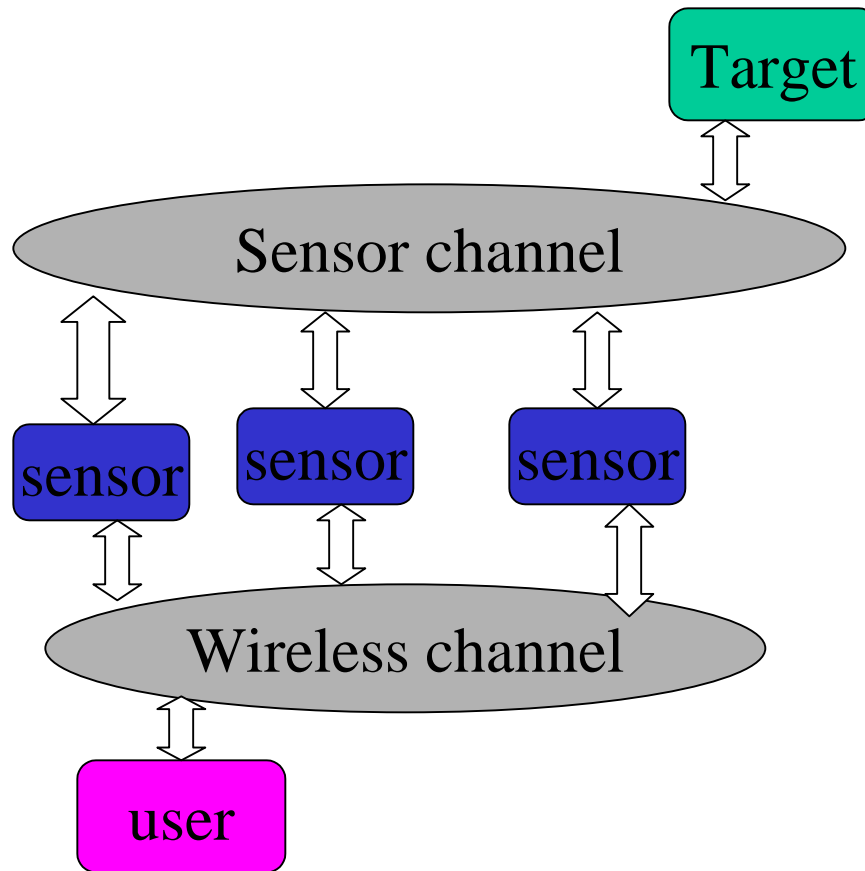
# SensorSim Architecture



# SensorSim Architecture Overview

- Sensor NW has three types of nodes:
  - *Sensor nodes*: monitor immediate environment, with many transducers
  - *Target nodes*: generates various stimuli for sensor nodes
  - *User nodes*: client and administration of sensor network
- Separate channels:
  - *Sensor channels*: communication among sensor nodes and target
  - *Network channels*: to user node or gateways and onward transmission to other network.
  - Concurrent transmission possible
  - Easier to model complex behavior of sensor nodes, reaction to multiple sensor signals.

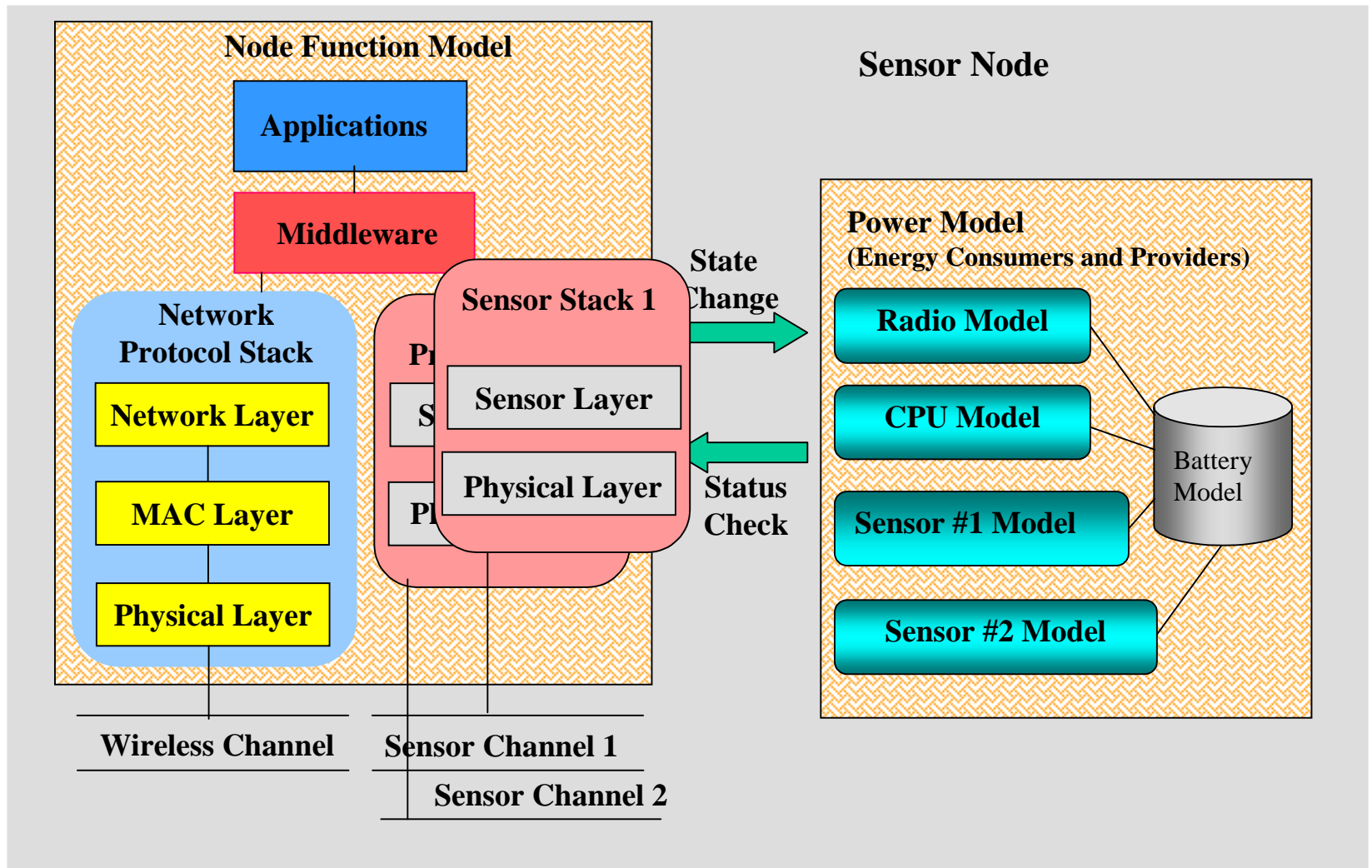
# Sensor Network Model architecture



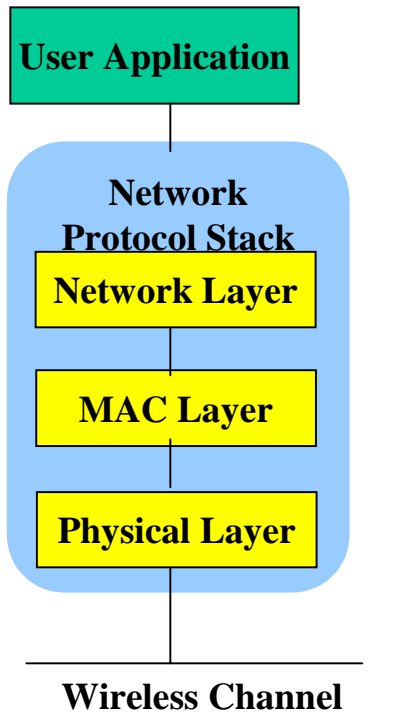
# SensorSim Model

- Sensor node  $\Rightarrow$  one wireless NW protocol stack, one or more sensor stack corresponds to as many transducers
  - Sensor stack detects stimuli, process it and forward them to application layer, which in turn process and send them to user node through wireless channel
  - A power model corresponding to energy producing-consuming hardware components is also provided. These component can stay at different power saving and performance states.
  - The algorithm in both the stacks control the mode of power states of hardware components. Also, performance of the algorithm depends on the mode.

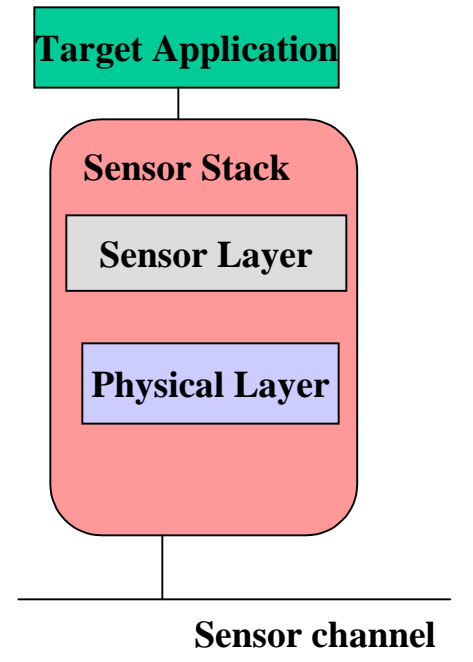
# Sensor Node Model in SensorSim



## User Node



## Target Node



# Framework of Sensor Network Simulation

- Node Placement & traffic generation
  - Performance of WSN is affected when topology of node distribution changes
  - Application requires a typical distribution (uniform for forest fire, Gaussian for perimeter defense)
  - Three types of traffics: *user-to-sensor* (command & queries), *sensor-to-user* (sensor reporting to user) and *sensor-to-sensor* (collaborative signal processing before reporting)

# Sensor Stack & Channel

- Sensor stack is a signal sink that is responsible for triggering the application layer every time a sensing event occurs
- Simple sensing scheme to elaborate signal processing can be implemented on sensor stack
- Sensor stack acts as a signal source in *Target Node* and contains signatures unique to the model
- *Sensor channel* model the medium of signal transmission (e.g. ground to carry seismic events).
- A good simulation tool should model varieties of mediums and type of sensors ( acoustic, infra red, ultrasonic)

# Battery Model

- Goal: increase the battery life time
- Need to study how different aspects of real battery behavior can affect the energy efficiency of applications
- $T = C/I$ ,  $C$  is capacity in Ah.  $I$  is discharge current
- Linear Model:
  - Linear storage of current. Assumes the maximum capacity is unaffected by discharge rate.
  - Allows user to see efficiency of user application by providing how much capacity is consumed. The remaining capacity after  $t_d$  can be expressed as  $C = C' - \int I(t)dt$  integral taken over period  $t = 0$  to  $t_d$
  - It assumes that the  $I(t)$  will stay same during the period, if operation mode does not change (radio switching from Tx to Rx)
  - Remaining capacity is computed when discharge rate is changed

# Battery Model

- Discharge rate dependent model:
  - Considers the effect of battery discharge rate on maximum capacity
  - Battery capacity efficiency factor  $K$  is introduced.  $K = C_{\text{eff}}/C_{\text{max}}$
  - Capacity  $C = K.C' - I . T_d$
  - $K$  varies with current  $I$  and is close to 1 when discharge rate is low and approaches 0 when discharge rate is high.

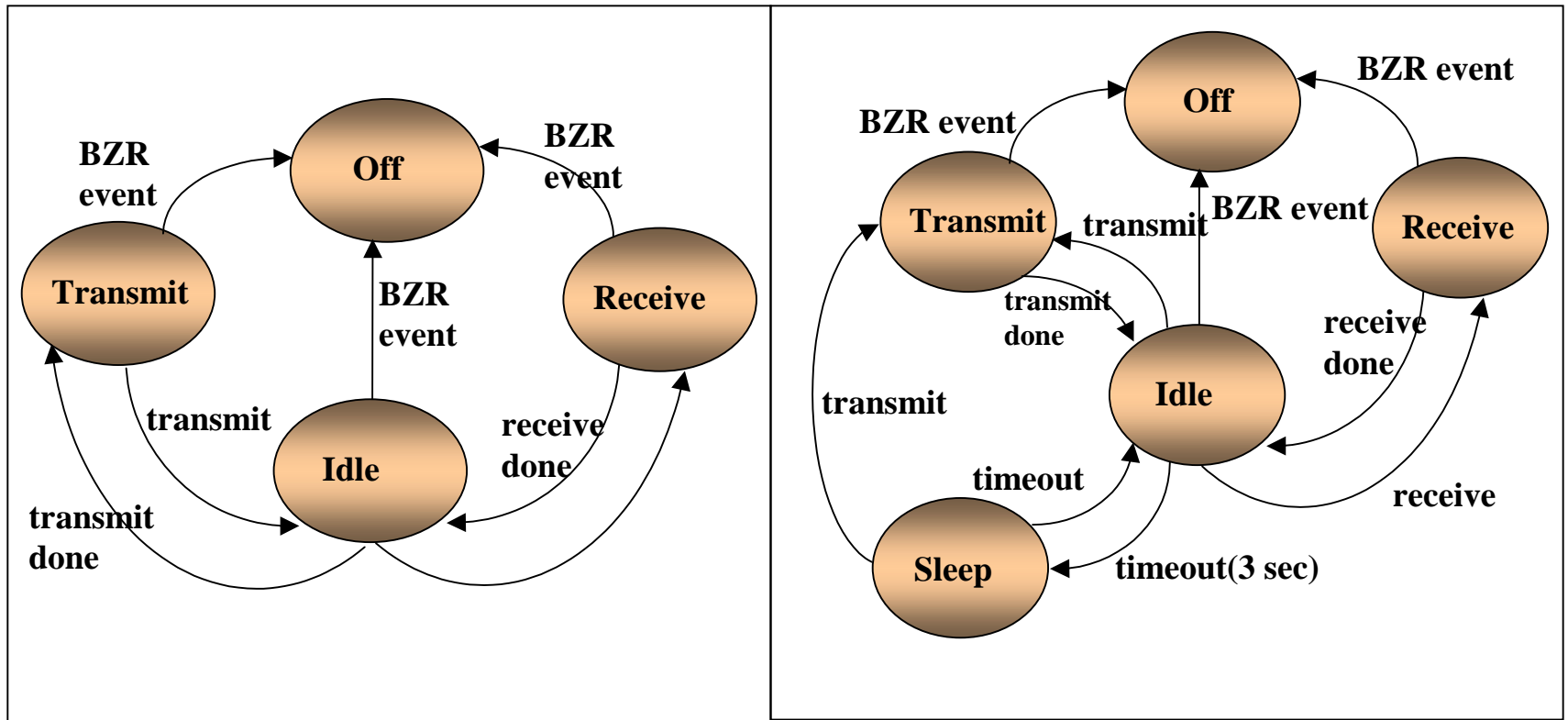
# Battery Model

- Relaxation Model:
  - Real-life battery exhibit a phenomenon called “*relaxation*”.(Fuller 94, Linden 95, Chiasserini 99)
  - When battery discharge rate is high, diffusion rate of active ingredients through the electrode & electrolyte falls behind. If high discharge is sustained, the battery reaches its end even if the active materials are still available.
  - However, if discharge current is either cut-off or reduced during the discharge, active materials catches up with depletion of the materials. It gives battery to recover the capacity lost at high discharge rate.
  - An analytical model has been used for SensorSim

# Case Studies

- Low rate/low power vs. high rate/ high power (Fig. 7 in the reference)
- Monitoring a moving vehicle in a sensor field
  - Study the effect of traffic on the sensing and communication traffic and evaluate the power management.

# Power Management Model



**Without Power Management**

**With Power Management**

# Conclusion

- Study of power consumption in sensor networks.
- Assignments for next class:
  - Read the reference paper
  - Critically examine the shortcomings: major and incremental
  - Bonus points: 1 per major, 0.2 for incremental. Maximum 5 points
  - Will discuss in the class on Friday
  - Must turn in single page remarks in the beginning of the class

# References

- Sung Park, A savvides & M B Srivastava, “Simulating Networks of Wireless Sensors”, Proceedings of the 2001 Winter Simulation Conference.