

# Management of Wireless Sensor Networks

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## Outline

Introduction to Management of WSN

Management Challenges

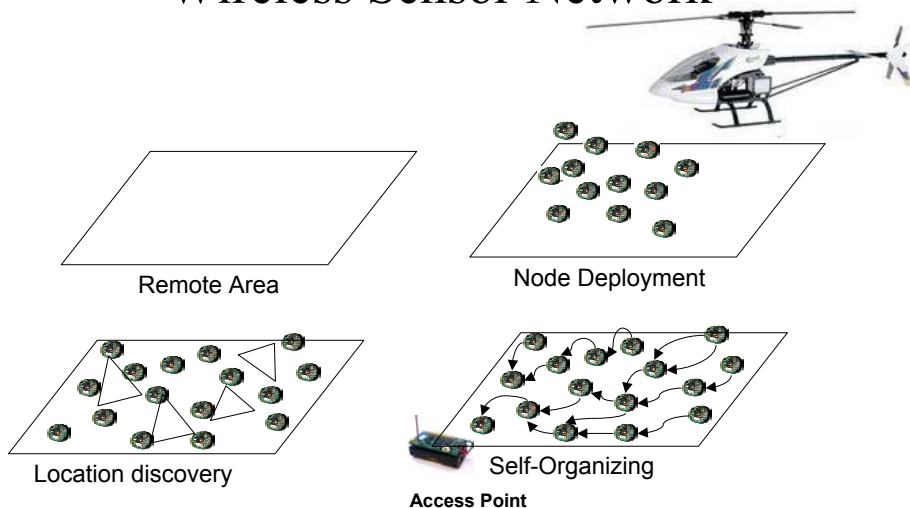
Management Dimensions

Conclusions

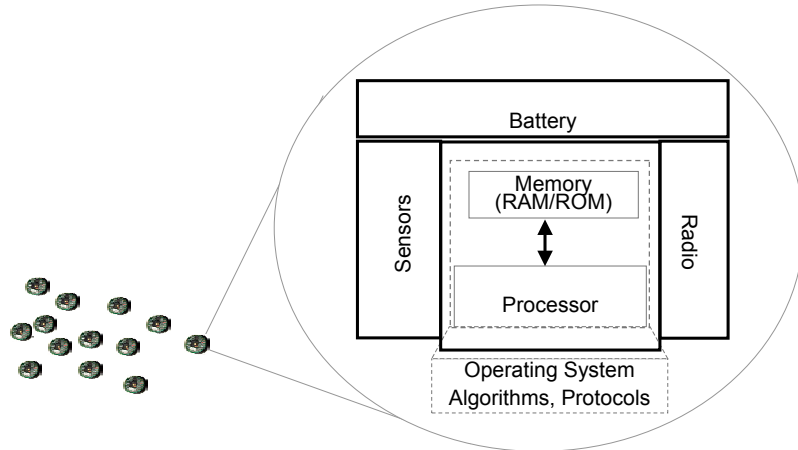
# Wireless Sensor Networks (WSNs)

- A WSN tends to be composed of hundreds or thousand of sensor nodes, which are launched over an environment to form a wireless ad hoc network
- The goal of a WSN is to monitor and sometimes to control an environment

## Wireless Sensor Network



# Wireless Sensor Nodes



# Wireless Sensor Nodes



Mica2 Motes

<b>Radio CC1000</b>	Modulation: FSK, 300 a 1000 MHz, Throughput: 76.8 kbps	Tx: 16.5 mA (868 MHz) Rx: 9.6 mA
<b>Processor Memory</b>	ATMEGA128L, 8-bit, 128 Kbytes Flash, 4 Kbytes RAM, ADC: 10 bits, 2.7 a 3.6 V	active: 8 mA idle: 1.6 mA sleep: 8 $\mu$ A
<b>Sensors</b>	Thermistor, cell photo, audio, accelerometer, magnetometer	active: 5 mA sleep: 5 $\mu$ A
<b>Battery</b>	2 AA (2850 mA-hr)	

**E<sub>transmission</sub> >>> E<sub>processing</sub>**

# Wireless Sensor Nodes

Sensor nodes tend to be designed with small dimensions



UC Berkeley: COTS Dust



UC Berkeley: DOT



JPL: Sensor Webs



UC Berkeley: Smart Dust

UFMG/Brazil

Sensonet Project MANNA<sup>team</sup>

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# Wireless Sensor Nodes

Due to the small dimension, sensor nodes have strong HW and SW restrictions in terms of processing power, memory capacity, battery lifetime, and communication throughput



UC Berkeley: COTS Dust



JPL: Sensor Webs



UC Berkeley: DOT



UC Berkeley: Smart Dust

UFMG/Brazil

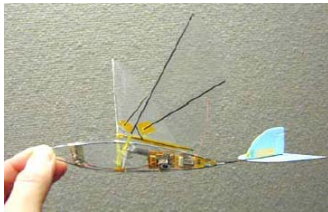
**E<sub>transmission</sub> >>> E<sub>processing</sub>**

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# Wireless Sensor Nodes

Wireless sensor nodes can be mobile



MEMS Sensors for Biomedical Applications. *Yu-Chong Tai*. NSF/ERC Industry Day, May 16-17, 2001

## Potential WSN Applications Environmental Monitoring

- Sensor nodes collecting different kinds of information
  - Flora and fauna (plants and animals)
  - Environment: fire risk, conditions at different heights



## Potential WSN Applications Environmental Monitoring

- Water quality, volume, throughput, etc
- Fire detection and prevention



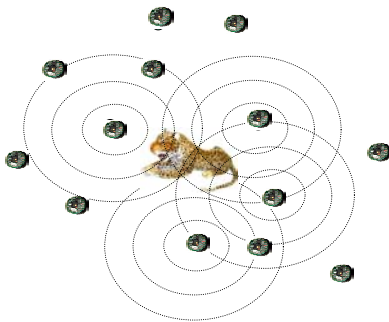
UFMG/Brazil



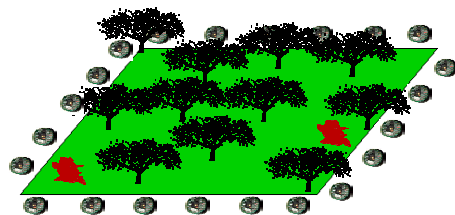
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## Potential WSN Applications Environment/Security



Wireless Sensor Network  
for helping biologists to better  
understand the environment



Wireless Sensor Network  
for monitoring intruders in a  
given perimeter

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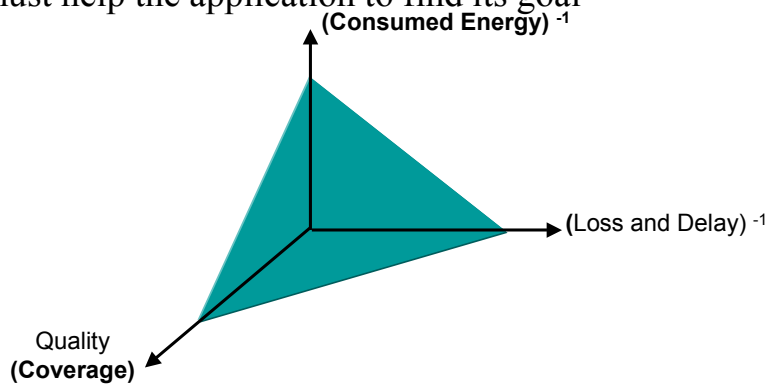
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# Potential WSN Applications Disaster Recovery



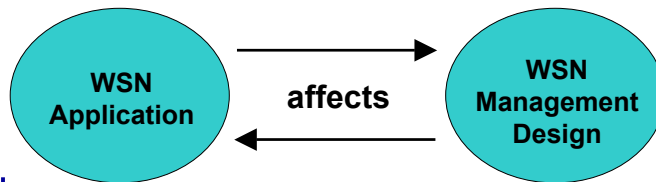
## WSN is application-specific

- Each application has its goal and management solution must help the application to find its goal



# Goal

- Main WSN management goal is to promote resources productivity and to maintain the quality of the services provided
- WSN are application-dependent and the management solution design is affected



# Developing management solutions

- The task of building management solutions for WSNs is not trivial
- This task becomes worse due to the physical restrictions of sensor nodes, in particular energy and bandwidth
- There are several significant differences in the management of traditional networks and WSNs

## Traditional Networks vs. WSNs

### Traditional networks:

- Are designed to accommodate a diversity of applications.
- Network elements are installed, configured, and connected in a way to provide different kinds of services.

### WSNs:

- Are typically designed for a specific application.
- Network elements are configured to provide a specific service.

## Traditional Networks vs. WSNs

### Traditional networks:

- Maintenance of components or resources by technicians is a normal fact.
- Network tends to follow a well-established planning of resources available.
- Faults should not be a common fact.

### WSNs:

- Often, there is no physical maintenance of nodes.
- It might be difficult to define a priori how resources will be spent in the network.
- Faults are a common fact.

## Traditional Networks vs. WSNs

### Traditional network:

- Different network elements might execute different applications.
- It is possible to have different security policies/mechanisms.

### WSN:

- Nodes often execute a common application in a cooperative way, i.e., there is clearly a common goal in the overall network.
- It may be difficult to introduce a security mechanism. In general, sensor nodes are not tamper-proof.

## Traditional Networks vs. WSNs

### Traditional network:

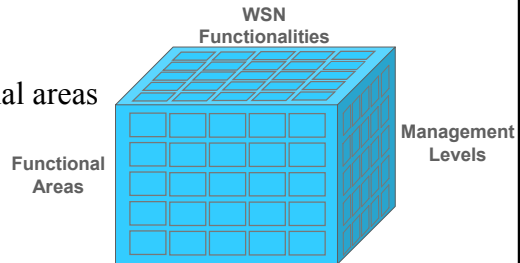
- Software are developed for a network element may have restrictions such as performance and response time.
- It is not common to have network elements with physical restrictions.

### WSN:

- Software are developed for a sensor node must consider its hardware limitations.
- Main physical restriction is energy available since batteries are often not recharged and all activities performed by the node must take into account the energy consumption.

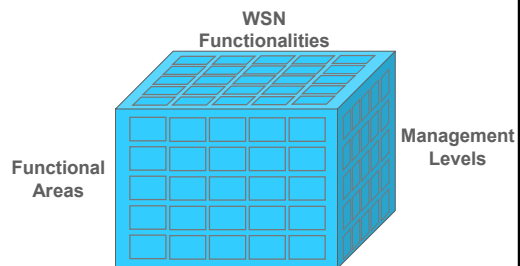
# Getting Started

- A good strategy is to deal with complex management situations by using management dimensions
  - Management levels
  - WSN functionalities
  - Management functional areas

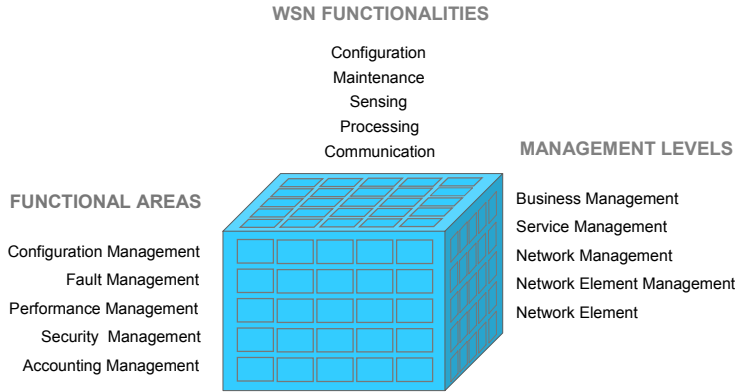


# Getting Started Design Philosophy

- Traditional management plays an important role
  - Management Levels
  - Functional Areas
    - ➔ Revisited considering particularities of WSNs
- Novel dimension
  - WSN Functionalities
    - ➔ Helps to reason about special features of WSNs

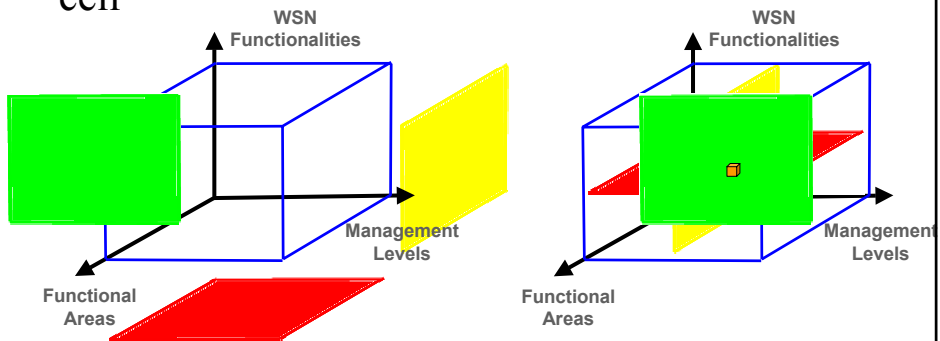


# Getting Started



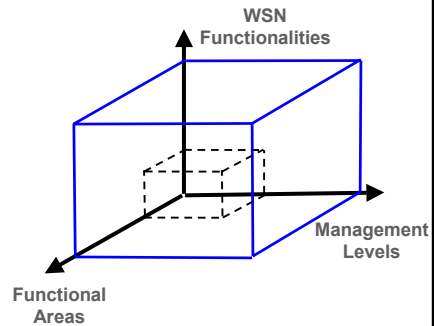
# Getting Started

The intersection of the three planes defines a cell



# Getting Started

- Each cell contains a set of management functions
- The three management dimensions must be considered in
  - the definition of a management function
  - in the establishment of an information model
  - in service composition
  - in the development of management applications



# Using the Management Cube

For example, the intersection of

is concerned with the info that is required to manage how

- network management level, (*Mgmt Level*)

NE entities (both physically and logically) are related

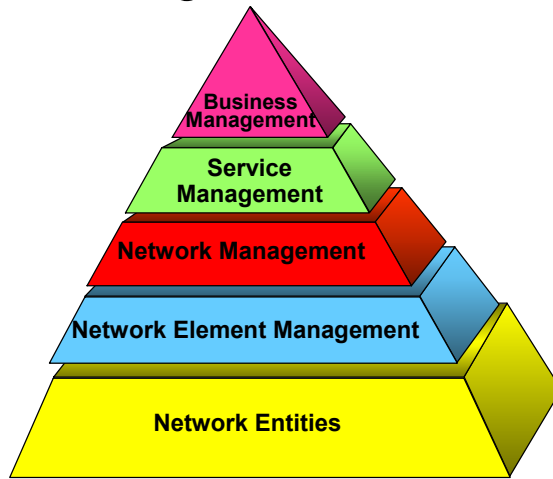
- configuration management, (*Functional area*) and

and configured to provide

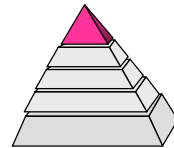
- communication (*WSN functionality*)

connectivity

# Management Levels

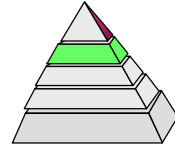


## Management Levels Business Management



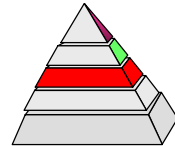
- Requirements that characterize a sensor network come from the objectives defined in the business management layer
- Design of WSNs depends on applications

## Management Levels Service Management



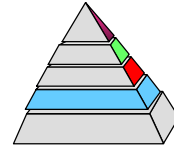
- A network service is defined by a set of parameters which determine the service level
  - Delay, accuracy, energy consumption
- The larger the number of monitored parameters, the larger the energy consumption and the lower the network lifetime
- Basic WSN services are
  - Sensing
  - Processing
  - Dissemination
- A WSN produces and transports its own data
  - ➔ It is self-service

## Management Levels Network Management



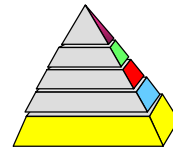
- Aims to manage a network as a whole, which is typically distributed over an extensive geographical area
- The relationships among sensor nodes are to be considered: collaboration, connectivity, and correlation

## Management Levels Element Management



- Basic functions are
  - power management: how a sensor node uses its energy
  - mobility management: plans, runs and registers the movement of sensor nodes
  - state management: how a sensor node manages the three management states defined for a node (operational, administrative, and usage)

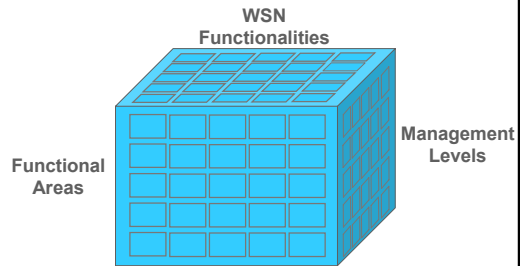
## Management Levels Network Element



- Represents the physical and logical components of a managed element
- Physical resources include sensor or actuator nodes which include power supply, processor, memory, sensor device, and transceiver
- Logical resources include communication protocols, application programs, correlation procedures, operating systems, and network services

# WSN Functionalities

- Looking at the characteristics of various WSN applications, five main WSN functionalities are established
  - Configuration
  - Sensing
  - Processing
  - Communication
  - Maintenance



# WSN Functionalities

## Configuration Functionality

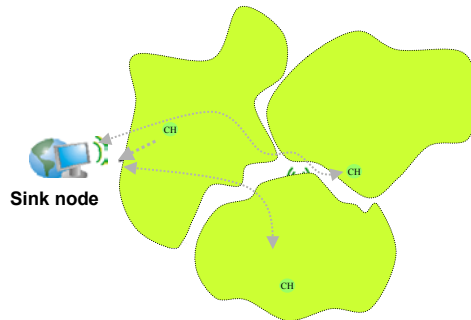
Considering the *network management level*, there are some aspects to characterize the WSN:

- Composition
  - Homogeneous: when all nodes have the same hardware capabilities
  - Heterogeneous: when the WSN is comprised of nodes with different capabilities
- Organization
  - Flat: when the nodes are not organized in groups
  - Hierarchical: when the nodes are organized in groups

## WSN Functionalities Configuration Functionality

Considering the *element management level*, there are some kinds of elements:

- Sink or Monitoring Node
- Source Sensor Node
- Cluster head



## WSN Functionalities Sensing Functionality

Considering the data gathering, a WSN can be classified as:

- Continuous: when sensor nodes collect data continuously along the time
- Reactive: when it answers to an observer's query or gather data corresponding to specific events occurring in the environment

# WSN Functionalities

## Communication Functionality

Considering the dissemination data, a WSN can be classified as:

- Continuous: when sensor nodes send their data to an observer continuously along the time
- On demand: when it answers to an observer's query
- Event-driven: when sensor nodes send data referred to specific events occurring in the environment
- Programmed: when nodes send data according to conditions defined by the application

# WSN Functionalities

## Processing Functionality

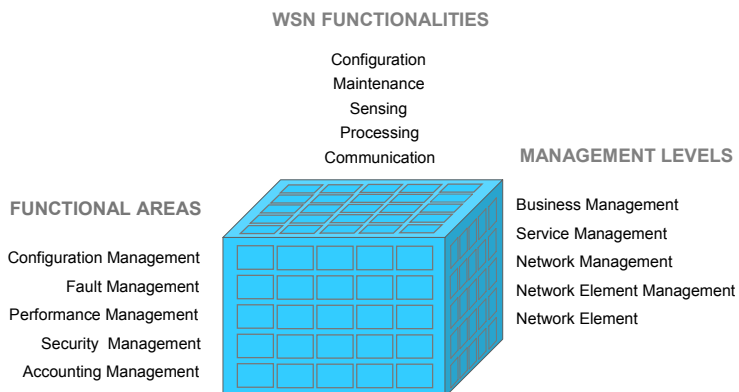
- Typically, there are two kinds of processing in WSNs:
  - Basic signal processing (e.g., simple translations based on calibrating data or threshold filters)
  - Correlation (consists of the conceptual interpretation of multiple data, leading to the attribution of a new meaning to the original data)

# WSN Functionalities

## Maintenance Functionality

- It is used in WSNs which can reconfigure, protect, optimize and heal themselves without intervention of human operators

# Management Functional Areas



## Management Functional Areas



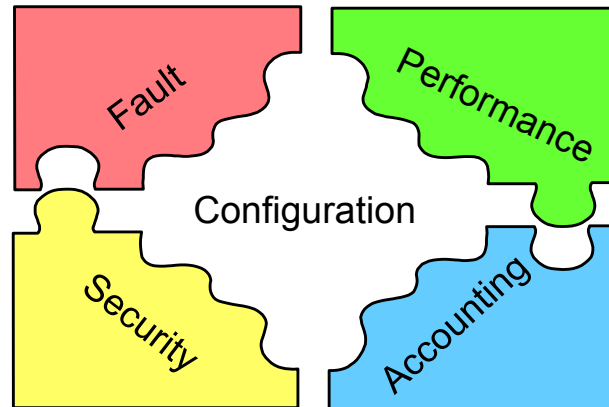
- There are several significant differences in the management of traditional networks and WSNs
- In this sense, management functional areas must be rethought considering WSNs features

## Management Functional Areas



- An error in the configuration or an unconsidered requisite during the planning may compromise all the functionalities of all other areas

## Management Functional Areas



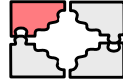
The fault, security, performance and accounting management functional areas are extremely dependent on the configuration functional area

## Management Functional Areas Configuration Management



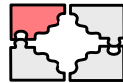
- The configuration management must provide basic features
  - Self-organization: is the property which the wireless sensor nodes must have to organize themselves to form the network
  - Self-configuration: nodes setup and network boot up must occur automatically

## Management Functional Areas Fault Management



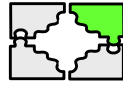
- Faults in WSNs are not an exception and tend to occur frequently, thus fault management is a critical function.
- This is one of the reasons that make WSN management different from traditional network management

## Management Functional Areas Fault Management



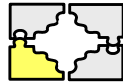
- Fault management must provide basic functionalities such as
  - Self-diagnostic: the network monitors itself and find faulty or unavailable nodes
  - Self-healing: the network prevents disruptions or that acts to recover itself or the node after the self-diagnostic

## Management Functional Areas Performance Management



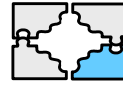
- The challenge in performance management is to perform this task without adversely consuming network resources
  - There is a trade-off to be considered: the higher the number of managed parameters, the higher the energy consumption and the lower the network lifetime
  - On the other hand, if enough parameter values are not obtained, it may not be possible to manage the network appropriately

## Management Functional Areas Security Management



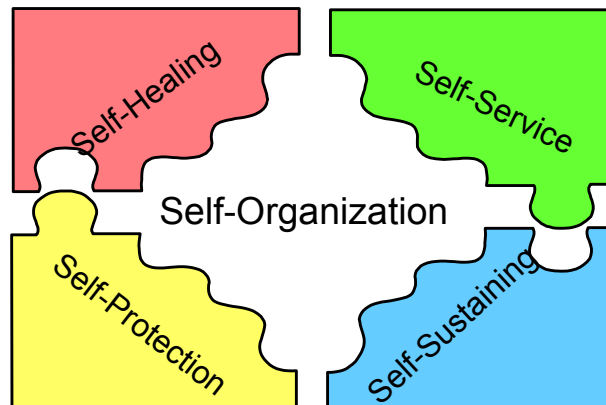
- Security functionalities for WSNs are intrinsically difficult to be provided because of their ad hoc organization, intermittent connectivity, wireless communication and resource limitations
- A WSN is subject to different safety threats: internal, external, accidental, and malicious

## Management Functional Areas Accounting Management



- It includes functions related to the use of resources and corresponding reports
- It establishes metrics, quotas and limits that can be used by functions of other functional areas
- It must provide self-sustaining functionalities

## Self-Management Functional Areas (proposed by Manna)



## Self-Management Functional Areas (proposed by Manna)

- The WSN management must be autonomic, i.e., self-managed (self-organizing, self-healing, self-optimizing, self-protecting, self-sustaining, and self-diagnostic), with a minimum of human interference, and robust to changes in the network states while maintaining the quality of the services

## Conclusions

- Management can promote resource productivity and QoS
- Energy management is, probably, the most important aspect
  - Network lifetime depends on energy rational use
- Management can improve the performance of WSNs with various configurations and offer to the observer relevant information

# Management of Wireless Sensor Networks

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<http://www.sensornet.dcc.ufmg.br>  
<http://www.mannasim.dcc.ufmg.br>

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## Biography

**Linnyer Beatrys Ruiz** is an Associate Professor of Electrical Engineering at the Federal University of Minas Gerais (UFMG), Brazil. Her areas of interest and research include computer networks, telecommunications and computer network management, and wireless sensor networks. She received a Ph.D. degree in Computer Science from UFMG, an M.S. degree in Electrical Engineering and Industrial Information from the Federal Center of Technological Education of Paraná (CEFETPR), Brazil, in 1996, and a B.S. degree in Computer Engineering from PUCPR. She held a post-doctoral position at the UFMG, 2004. She is an expert in telecommunications management network (TMN). Since 1993 she has participated and coordinated research groups on TMN. Currently, she is coordinating the WSN group in the Electrical Engineering Department of UFMG and is leading the Manna research team.

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