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# WIRELESS SENSOR NETWORKS

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***Abstract: Wireless sensor networks are appealing to researchers due to their wide range of application potential in areas such as target detection and tracking, environmental monitoring, industrial process monitoring, and tactical systems. The rising field of wireless sensor network (WSN) has potential benefits for real-time monitoring of a physical phenomenon. The Wireless sensors continuously monitor the physical process and transmit information to the base station.. Various MAC protocols with different objectives were proposed for wireless sensor networks. In this paper, we first outline the sensor network properties that are crucial for the design of MAC layer protocols. Then, we describe several MAC protocols proposed for sensor networks emphasizing their strengths and weaknesses. Finally, we point out open research issues on MAC layer design.***
***Index Terms: MAC Protocols, Sensor Networks, Survey***

## I. INTRODUCTION

Sensor technologies, the sensor nodes are used in wide range of applications in environmental monitoring [1]. It can hold potential to revolutionize segments of the economy and life. There could be one or few sink nodes and a fixed number of sensor nodes in Wireless Sensor Networks and all the sensor nodes have contact with the base station. A Wireless Sensor Network has been designed to perform the high-level of information processing tasks like detection, classification and tracking. The energy of nodes, communication computing and storage capability in Wireless Sensor Networks are limited Unlike other wireless networks, it is generally hard (or impractical) to charge/replace the exhausted battery, which gives way to the primary objective of maximizing node/network lifetime, leaving the other performance metrics as secondary objectives. Since the communication of sensor nodes will be more energy-consuming than their computation, it is a primary concern that the communication is minimized while achieving the desired network operation. the key MAC protocols proposed for sensor networks listing their advantages and disadvantages. Moreover, the protocols that propose the integration of MAC layer with other layers are also investigated . Finally, Section IV concludes the survey on MAC protocols with a comparison of investigated protocols and provides a future direction to researchers for open issues that have not been studied thoroughly.

## II. MAC LAYER RELATED SENSOR NETWORK PROPERTIES

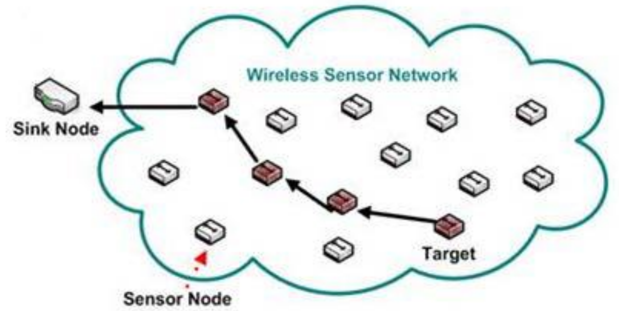
Maximizing the network lifetime is a common objective of sensor network research, since sensor nodes are assumed to be disposed when they are out of battery. Under these circumstances, the proposed MAC protocol must be energy-efficient by reducing the potential energy wastes presented in Section II.A. Types of communication patterns that are observed in sensor network applications should be investigated since these patterns are used to extract the behavior of the sensor network traffic that has to be handled by a given MAC protocol. Categorization of the possible communication patterns are outlined in Section II.B. Afterwards, the properties that must be possessed by a MAC protocol to suit a sensor network environment are presented in Section II.C.

### *A. Reasons of Energy Waste*

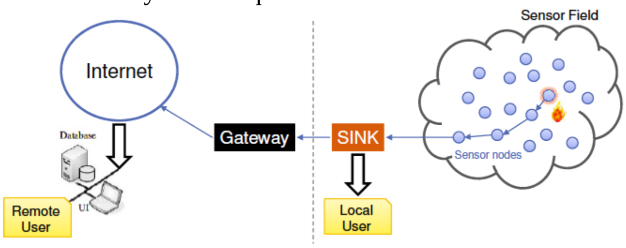
When a receiver node receives more than one packet at the same time, these packets are called "collided packets" even when they coincide partially. All packets that cause the collision have to be discarded and the re-transmissions of these packets are required which increase the energy consumption. Although some packets could be recovered by a capture effect, a number of requirements have to be achieved for its success. The second reason of energy waste is overhearing, meaning that a node receives packets that are destined to other nodes. The third energy waste occurs as a result of control packet overhead. Minimal number of control packets should be used to make a data transmission. One of the major sources of energy waste is idle listening, i.e., listening to an idle channel to receive possible traffic. The last reason for energy waste is overemitting, which is caused by the transmission of a message when the destination node is not ready. Given the facts above, a correctly-designed MAC protocol should prevent these energy wastes.

### *B. Communication Patterns*

Kulkarni et al. defines three types of communication patterns in wireless sensor networks [1]: broadcast, convergecast, and local gossip. Broadcast type of

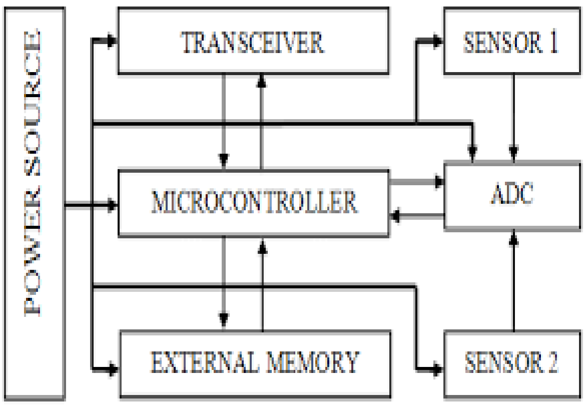



In alternative cases of ground access space of objectives needs to monitor is dangerous and troublesome. So sensors are the only solution in harsh environment monitoring. While not locating the position, the solely way to allow adequate target coverage by sensors to use multiple sensors than the fastened range. High sensor density will increase the chance of target coverage. The sensors are placed within target proximity. In sensing network, the main problem is network lifetime. The cost and size of network limits the accessible energy within sensor network to sense the Physical phenomenon. A general approach to energy saving is to use mechanisms for economical energy management. This technique is applied on programming communication pattern is generally used by a base station (sink) to transmit some information to all sensor nodes of the network. Broadcasted information may include queries




III. GENERATIONS AND ARCHITECTURE OF WSN

Wireless Sensor Networks evolved through many generations starting from simple sensors deployed in fields for military applications to hazardous industrial applications. Now, the sensor networks is mainly classified into three fields based on the applications i.e. in WSN, energy consumption is major issue and in MANET's, mobility of nodes consider as the major challenge for various mobile applications. Furthermore, in VANET's, important challenge is to minimize the path length Multi-media Wireless sensing networks are enabled to see and track events in the variety of multimedia system like as video, audio and imaging. Multi-media Wireless sensing networks includes sensing nodes which have inbuilt microphones and cameras. These sensing nodes can be connected with other nodes

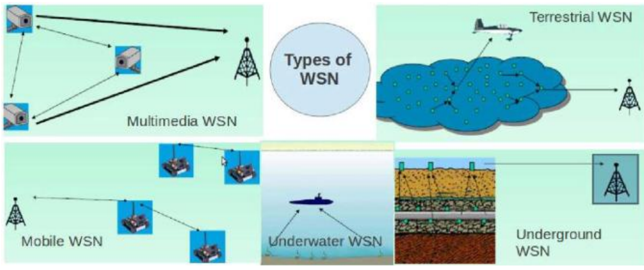



in the network. In order to get coverage, these nodes are located in planned

Types of WSNs

Presently many WSNs are deployed on land, underground and underwater.

They face different challenges and constraints depending on their environment. We present five types of WSNs [12] as shown in Figure.



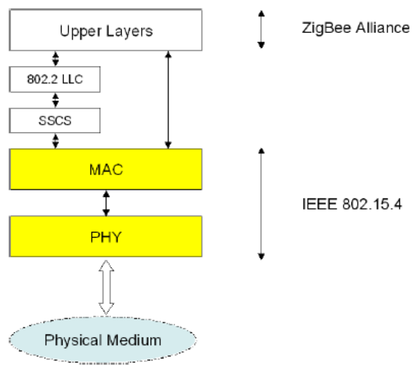

The broadcast type communication pattern should not be confused with broadcast type packet. For the former, all nodes of the network are intended receivers whereas for the latter the intended receivers are the nodes within the communication range of the transmitting node.

In some scenarios, the sensors that detect an intruder communicate with each other locally. This kind of communication pattern is called local gossip, where a sensor sends a message to its neighboring nodes within a range. The sensors that detect the intruder, then, need to send what they perceive to the information center. That communication pattern is called convergecast, where a group of sensors communicate to a specific sensor. The destination node could be a clusterhead, data fusion center, base station.

In protocols that include clustering, clusterheads communicate with their members and thus the intended receivers may not be all neighbors of the clusterhead, but just a subset of the neighbors. To serve for such scenarios, we define a fourth type of communication pattern, multicast, where a sensor sends a message to a specific subset of sensors.

Properties of a Well-defined MAC Protocol

To design a good MAC protocol for the wireless sensor networks, the following attributes must be considered [2]. The first attribute is the energy efficiency. We have to define energy efficient protocols in order to prolong the network lifetime.




The IEEE 802.15.4 standard defines two types of network nodes: full-function device (FFD) and reduced-function device (RFD). RFDs are very basic nodes with little processing and memory resources. They can only act as end-systems in the network and communicate with FFDs. Whereas FFDs are able to fully implement the standard. FFDs can act as coordinators (Per-
sonal Area Networks (PAN) or full network coordinators) and communicate with both FFDs and RFDs. IEEE 802.15.4

supports two types of network topologies; star and peer-to-peer topology for communication between network devices as shown in Figure 5. In the star topology, all the devices communicate with a central controller (FFD) while the peer-to-peer topology allows more complex network formations to be implemented, such as mesh network- ing topology. A peer-to-peer network can be ad-hoc, self-organizing, and self-healing. Star topology is preferred when coverage area is small and low latency is required by the WSN application. Whereas peer-to-peer topology is suitable for a large coverage area where latency is not a critical issue. The original 2003 version supports 868/915 MHz low bands with data rates of 20 and 40 kbps, and 2.4 GHz high bands with a rate of 250 kbps. Other important attributes are scalability and adaptability to changes. Changes in network size, node density and topology should be handled rapidly and effectively for a successful adaptation. Some of the reasons behind these network property changes are limited node lifetime, addition of new nodes to the network and varying interference which may alter the connectivity and hence the network topology. A good MAC protocol should gracefully accommodate such network changes. Other typical important attributes such as latency, throughput and bandwidth utilization may be secondary in sensor networks. Contrary to other wireless networks, fairness among sensor nodes is not usually a design goal, since all sensor nodes share a common task.

*Sensor-MAC (S-MAC)*

Locally managed synchronizations and periodic sleep-listen schedules based on these synchronizations form the basic idea behind the Sensor-MAC (S-MAC) protocol [2]. Neighboring nodes form virtual clusters to set up a common sleep schedule. If two neighboring nodes reside in two different virtual clusters, they wake up at listen periods of both clusters. To reduce the power consumption incurred by the pre-determined fixed-length preamble, WiseMAC offers a method to dynamically determine the length of the preamble. That method uses the knowledge of the sleep schedules of the transmitter node's direct neighbors

Advantages: The simulation results show that WiseMAC performs better than one of the S-MAC variants . Besides, its dynamic preamble length adjustment results in better performance under variable traffic conditions. In addition, clock drifts are handled in the protocol definition which mitigates the external time synchronization requirement.

WiseMAC

Spatial TDMA and CSMA with Preamble Sampling protocol is proposed in [3] where all sensor nodes are defined to have two communication channels. Data channel is accessed with TDMA method, whereas the control channel is accessed with CSMA method. Enz et al. proposed WiseMAC [4] protocol which is similar to Hoiydi et al.'s work [3] but requires only a single-channel. WiseMAC protocol uses non-persistent CSMA (np-CSMA) with preamble sampling as in [3] to decrease idle listening. In the preamble sampling technique, a preamble precedes

## IV. CHARACTERISTICS

A Wireless Sensor Network is fundamentally a network of nodes that can jointly sense the physical environment. The main characteristics of WSNs are flexibility, Maintainability, Scalability, self-monitoring, property of fault tolerance [24, 25, 26]. Moreover, it provides quality of services and it can fulfil its task in harsh environment. Some problems can only be resolved by WSN like geographic scoping square measure. As compared with other networks, the services provided by wireless sensor network are real time and reliable.

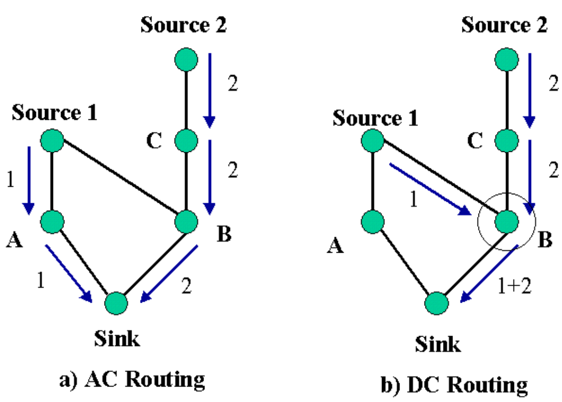
Topology and Coverage Control Topology control is one of the fundamental problems in WSNs. It has great importance for prolong lifetime, reducing radio interference, increasing the efficiency of media access control protocols and routing protocols. It also ensures the quality of connectivity & coverage and increase in the network service as well. A significant progress in research can be seen in WSNs topology control. Many topology control algorithms have been developed till date, but problems such as lack of definite and practical algorithm, lack of efficient mea- surement of network performance and idealness of mathematical model still exist.

ROUTING IN WSN

A sensing element node has restricted sensing and computation capacities, communication capability and power. These nodes can communicate with one another for obtaining information either directly or through other intermediate nodes. Therefore every node in an exceedingly sensing element network acts as a router within the network. We start with simple models of routing schemes which use data aggregation (which we term data-centric), and schemes which do not (which we term address-centric). In both cases we assume there are some common elements -the sink first sends out a query/interest for data, the sensor nodes which have the appropriate data then respond with the data. They differ in the manner the data is sent from the sources to the sink:

Address-centric Protocol (AC): Each source independently sends data along the shortest path to sink based on the route that the queries took ( "end-to-end routing" ).

Data-centric Protocol (DC): The sources send data



DATA AGGREGATION

Data aggregation is the combination of data from different sources, and can be implemented in a number of ways. The simplest data aggregation function is duplicate suppression - in the example of figure 1, if sources 1 and 2 both send the same data, node B will send only one of these forward. Other aggregation functions could be max, min, or any other function with multiple inputs. For our modelling purposes in this paper we make a simplifying assumption - the aggregation function is such that each intermediate node in the routing transmits a single aggregate packet even if it receives multiple input packets.

DELAY DUE TO DATA AGGREGATION

Although data aggregation results in fewer transmissions, there is a tradeoff - potentially greater delay because data from nearer sources may have to be held back at an intermediate node in order to be aggregated with data coming from sources that are farther away.

Bluetooth and Bluetooth Low Energy (BLE)

Bluetooth is a wireless technology for short-range and cheap devices intended to replace the cables in WPANs. It operates in the 2.45 GHz ISM band and uses frequency hopping to combat interference and fading. Bluetooth can cover a communication range of 10-100 m and allows data rate up to 3 Mbps. It was standardized as IEEE 802.15.1, but the standard is no longer maintained. Currently, Bluetooth is managed by the Bluetooth Special Interest Group, which adopted Bluetooth Core Specification Version 4.0 in 2010.

Bluetooth v4.0 [63] is the most recent version. Itntroduced Bluetooth Low Energy (BLE) technology [52] that enables new low-cost Bluetooth Smart devices to operate for months or years on tiny, coin-cell batteries. Potential markets for BLE-based devices include healthcare, sports and fitness, security, and home entertainment. BLE operates in the same 2.45 GHz ISM band as classic Bluetooth, but uses a different set of channels. Instead of Bluetooth’s 1-MHz wide 79 channels, BLE has 2-MHz wide 40 channels.

CHALLENGES IN WIRELESS SENSOR NETWORKS

The major technical challenges for realization of WSNs are identified as follows [51, 52, 58].

Resource constraints [53]: The planning and implementation of WSNs square measure forced by three scarce resources:

a) Limited energy.
b) Limited memory.
c) Limited computational capability.

management approach should be the balance of subsequent goals:

• Minimize Size of stored information: Since sensors have restricted storage offered to them, minimizing the dimensions of information that require to be keep ends up in improved coverage because the network will continue storing data for extended periods of time.

Minimize Energy Consumption: Most of the sensors area unit are battery-powered and so energy could be a scarce resource, so storage management must be energy efficient.

Maximize information Retention or Coverage: Aggregated information is the primary goal of the network. If storage is affected, information re-allocation should be applied efficiently to ensure coverage for new data.

Dynamic topologies and harsh environmental conditions: In Physical environments, the topology and property of the network could vary as a result of link and sensor-node failures.

Quality-of-service needs: The big variety of applications envisaged on WSNs can have completely different QoS requirements and specifications

Data redundancy: Attributable to the high density within the network topology, device observations can be redundant.

Packet errors and variable-link capacity: Compared to wired networks, Capability of every wireless link depends on the interference level and high bit error rates in transmission

Security: Security ought to be a necessary feature within the architecture of WSNs to make the communication safe from external denial-of-service attacks and intrusion. WSNs have special characteristics that modify ways of security attacks. Passive attacks are carried out by eavesdropping on transmissions.

Integration with web and alternative networks: it is necessary for the development of sensing network to provide several services which give access to retrieve any information at any time

V. STORAGE MANAGEMENT IN WSN

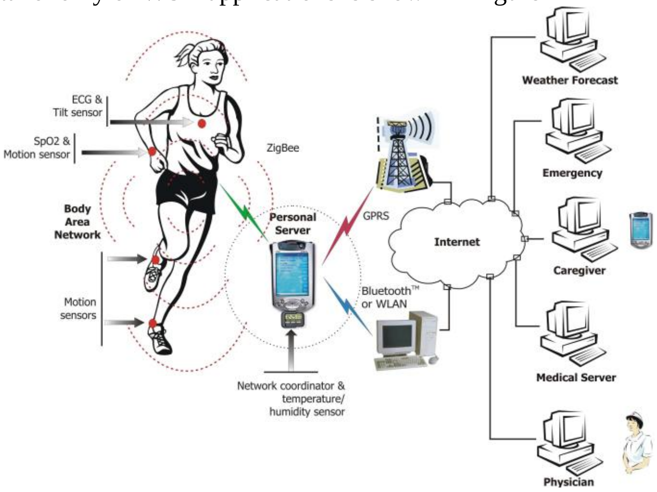
Storage management is an area of sensor network analysis that starts to attract attention of researchers. For storage management, data gathered by sensors is not transmitted to the sink in limited time period. In such applications, the information should be keep, a minimum of briefly, among the network till later collected by the sink. Therefore, storage becomes a primary resource, additionally to energy, that determines time period and coverage of the network.

Mobility management Mobility is one of the most important issues in next generation networks. As WSNs are becoming the next elements of the future Internet, it is crucial to study new models that also support mobility of these nodes. WSNs are applicable in variety of cases that make it difficult to produce a standard mobility scenario. Following are some cases where the mobile support is necessary presented in Camilo (2008). Intra WSN device movement is probably the most common scenario in WSNs architectures, where each sensor node has the ability to change from its local position at run time without losing the connectivity with the sensor router (SR). In the case of inter WSN device movement, sensor nodes move between different sensor networks, each one with its SR responsi-ble to configure and manage all the aggregated devices.

Security and Privacy Concern The field that paid less attention is the privacy concern on information being collected, transmitted, and analyzed in a WSN. Such private information of concern may include payload data collected by sensors and transmitted through the network to a centralized data processing server. The location of a sensor initiating data communication, and other such context information, may also be the focus of privacy concerns.

Application domains and deployments
WSNs have been adopted in a large number of diverse application domains. It is envisioned that in future everyday objects will be embedded with sensors to make them smart. Smart objects can explore their environment, communicate with other smart objects, and interact with humans. A taxonomy of WSN applications is shown in Figure




a sensor network deployment for habitat monitoring, biodiversity map-ping; to observe wildlife, flood detection, forest fire detection, and precision agriculture. Furthermore, in the civil sector, WSNs have generated a lot of in-terest from their smart infrastructure applications, such as smart grids, smart energy metering, smart transport and traffic management, smart roads, etc. Structural health monitoring enables detecting the health status of structures using a network of accelerometers and strain gages.

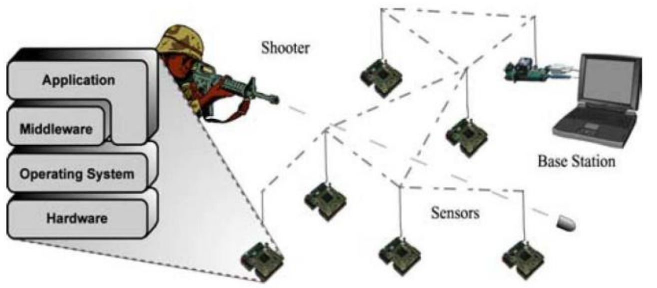



Fig. System architecture in the counter-sniper application PinPtr

PinPtr: is a counter-sniper system developed to detect and locate shooters as shown in Figure. The ad-hoc acoustic sensor network detects the muz-zle blast and the acoustic shock wave that originate from the sound of gunfire. Sensors route their measurements to the base station to compute the shooter'slocation.

CenWits: is a search-and-rescue system designed to determine an approxi- mate small area where search-and-rescue efforts can be concentrated [73]. The system consists of mobile sensors worn by subjects (people), access points that collect information from these sensors and GPS receivers, and location points to provide location information to the sensors.

ZebraNet: is a sensor-based tracking system developed to track animal migra-tions. ZebraNet consists of a mobile sensor network created by attaching.


Fig. The ZebraNet sensor collar, attached to a Zebra

Volcanic monitoring: A wireless sensor network of 16 sensor nodes equipped with seismo-acoustic sensors was deployed on Volcan Reventador in northern Ecuador to monitor volcanic eruptions . The network collected seismic and acoustic data on volcanic activity over 3 km and transmitted the collected data through a multi-hop routing and over a long-distance radio link to a base station at the volcano observatory

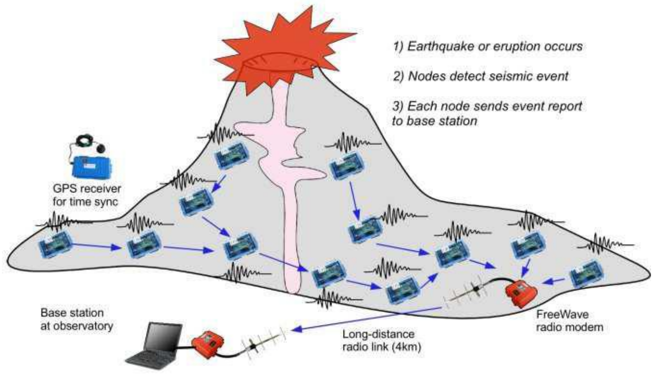



Fig. Volcan Reventador deployment for volcano monitoring

Target tracking and parameter estimation: applications involve many different levels of complexities and different blocks in system design. The ap- plication can vary from just tracking a single spatial phenomenon, such as average road speeds to more complex scenarios, such as tracking multiple het-erogeneous and mobile targets with multiple time varying parameters. Some applications for such tracking capabilities include Military applications involving tracking different persons, vehicles and objects, such as bullets (as in Pinptr example provided before) and objects can have heterogeneous shapes and velocities. Wildlife applications (e.g., ZebraNet) include tracking the num-ber and kinds of animals and vehicles in a large area to observe the wildlife and prevent poaching. In general, the applications for such capabilities are numer- ous. Since such capabilities require advanced costly devices, it is challengingto do with many low cost, low performance sensors with simple functions, that are distributed randomly. This requires highly-effective intelligent collabora-tion among sensor nodes, energy efficiency and dynamic reconfigurability toadapt to the characteristics of mobile targets.

Positioning in the industry:
Though the research in the field of WSN is about a decade old, this is con-sidered as a new research area as reflected in the rise in WSN research anddevelopment budgets every year. The focus is on developing new communica-tion protocols and management services to meet the specific requirements of sensor nodes such as limited power, processing capacity and storage. Some hot research topics in WSN are related to topology creation, control and mainte-nance. We describe here some leading research projects and work in the domain of WSNs

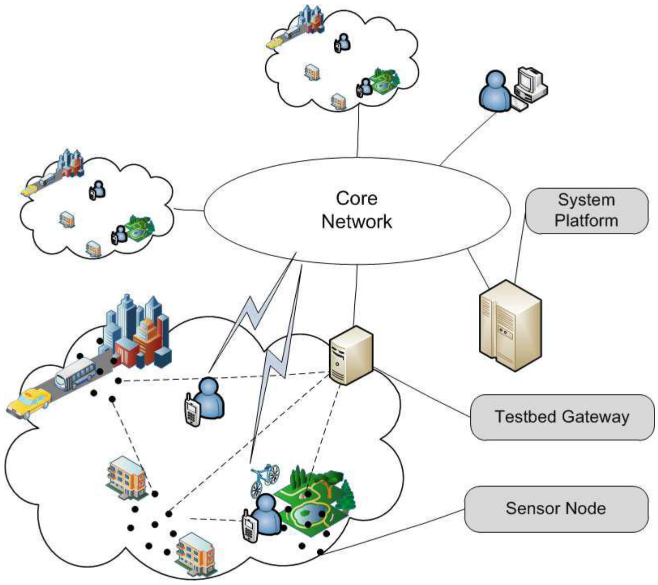



Fig. A high-level architecture of SmartSantandar city.

Smart Santander Project : has developed a state of the art smart city in the Spanish port city of Santander . It aims at designing, deploy- ing and validating a platform composed of sensors, actuators, cameras and screens in Santander to offer useful information to residents. In this project, 750Waspmotes have been deployed in different locations within the city to monitor different parameters, such as noise, temperature, luminosity, CO and free parking slots.

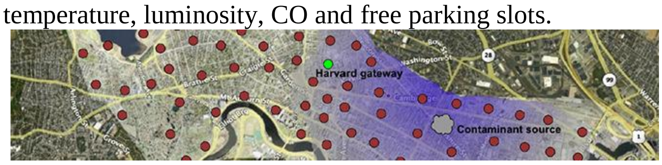



Fig. CitySense: Conceptual deployment of sensor nodes in Cambridge

CitySense : is an open urban-scale WSN testbed that deploys 30 outdoor nodes (target is 100 nodes) on buildings and streetlights around the Cambridge city. It is a mesh like testbed with high power radios and embedded PCs.Its nodes support various sensors for monitoring weather conditions and airquality.

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