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Wireless Sensor Networks

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Abstract—Wireless Sensor Networks (WSNs) are one of the most swiftly developing information technologies and have a variety of applications in Next Generation Networks (NGNs). The major goal of this research paper is to give recent advances and advanced results covering both elemental principles, and use cases of WSNs in NGNs. This paper provides design techniques and guidelines, overview of existing and emerging techniques used in wireless sensor networks. It will also provide some kind of information about ITU-T developments concerning WSNs, including Sensor Networks (USNs), Sensor Control Networks (SCNs), and Machine-Oriented Communications (MOC) concerns. In addition, this technical paper also covers different topologies used in WSNs. This research paper should appeal to ITU-T contributors working on NGNs development, analysts, networking designers, engineers and graduate students interested in WSNs.

Keywords— WSNs;NGNs;ITU-T;USNs;SCNs;MOC.

I. Introduction

Wireless Sensor Network (WSN) invokes to a group of dedicated sensors for monitoring and recording the physical conditions of the environment and arrange the collected data at a central location. WSNs measure environmental conditions like temperature, sound, pollution content, humidity, wind speed, and so on.

These are similar to wireless network in the sense that they rely on wireless connectivity and rapid formation of networks so that sensor data can be transported wirelessly. Sometimes they are called dust networks, referring to minute sensors that are as small as dust. WSNs are spatially distributed sensors to *monitor* physical or environmental conditions, such as temperature, sound, pressure, etc. and to pass their data through the network to main locations, cooperatively. The more a modern network is bi-directional, the more it enables control of sensor activity. The development of wireless sensor networks was based on military applications like battlefield surveillance. Today such networks are used in many industrial and user applications, such as industrial process monitoring and machine health monitoring, and so on.

The WSN comprises of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or numerous) sensors. Each such sensor network node has typically many parts: a radio transceiver with an internal antenna or linked to an external antenna, a microcontroller, an electronic circuit for combining with the sensors and an energy source, usually a battery is used. The topology of the WSNs can differ, varying from a simple star network to an advanced multi-hop wireless mesh network.

II. Overview of Network Architecture

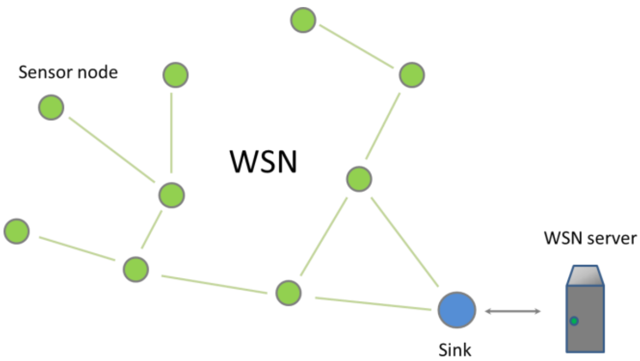

Fig 1: An example of a WSN

Figure 1 represents an example of a WSN. Here we can see a WSN which consists of nine sensor nodes and a *network sink*, which also functions as a *gate*. Each sensor node is a device which consists of a transceiver, a microcontroller, and a sensitive element (Figure 2). Normally sensor node is an autonomous device. Every sensor node in WSN measures some physical conditions, such as temperature, humidity, pressure, and converts them into digital data. Sensor node can also process and store the measured data before transmission. Network sink is kind of a sensor node whose function is to aggregate useful data from other sensor nodes. Network sink necessarily has to have a stationary power source and which is connected to a *server* which processes data received from WSN. In case it is necessary to provide a remote access to WSN, network sink also functions as a gate, and it is possible to interact with WSN through global network, like the Internet.

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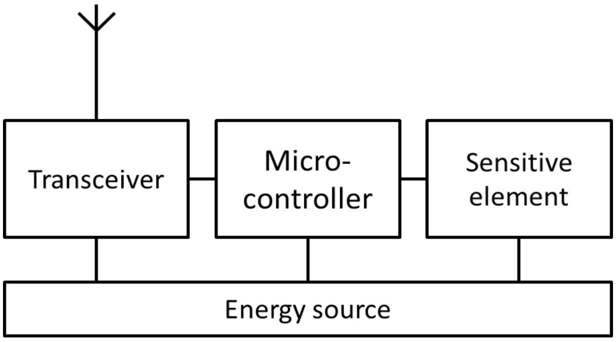

Figure 2: Sensor node inner structure

In WSNs, communication is implemented by a wireless transmission channel that uses low power transceivers of sensor nodes. Sensor node's transceiver has limited energy content, because of which, it is not possible for the most spatially remote sensor nodes to transmit their data directly to the sink. So, in WSN each sensor node transmits its data to only a few nearest sensor nodes which, in turn, retransmit those data to their nearest sensor nodes and so on. Because of this, after a lot of retransmissions, data from all the sensor nodes reach the network sink.

Inside the sensor node, a microcontroller (precisely, its firmware) accounts for data collecting and connection with rest of the sensor nodes. Microcontroller firmware has a set of algorithms that control the transceiver and the sensing element. Simultaneously, in addition to data collecting and transmitting their own measurements, sensor nodes take part in data transmission from other remote sensor nodes, i.e. in providing connectivity to the whole WSN.

Another important characteristic feature of WSN is the self-organization of intra-network connectivity. Network self-organization makes it feasible for randomly spatially distributed sensor nodes and sinks to form a WSN automatically. Furthermore, when a network is in use and there are connection problems with some sensor nodes, it doesn't mean that the whole system will fail. In that case WSN simply changes its mode of operation to not use the lost nodes for data transmission. This feature of WSNs is what noticeably simplifies their installation and maintenance, and it also allows creating WSNs with thousands of nodes because there is no need to change the network's mode manually while adding new nodes. WSN's self-organization feature in general makes WSN more reliable because it allows network reconstruction to be done in real-time mode, and as a result, the WSN quickly reacts to the environment changes or sensor nodes failures. In addition to this, self-organization algorithms can provide optimization of energy consumption for data transmission.

Data that is collected by all the sensor nodes are usually transmitted to the server which provides the final processing of all the information that is collected by the sensor nodes. In general, WSN includes one or selective sinks and gates which are collecting data from all the sensor nodes and transmitting this data for subsequent processing. At the same time, gate transmits the data from the WSN to other networks. In this way communication between WSNs and other external networks, like the Internet, is being provided.

III. WSNs WITH THE CLUSTER STRUCTURE

As energy content of sensor nodes is limited and non-renewable, it is important to use it in the most economical way. Figure 3 illustrates the data streaming from sensor nodes to sink. Sink is responsible for collecting data from all the sensor nodes periodically. In the figure, every arrow between sensor nodes shows a transfer of a portion of measurements for a single cycle of data collection.

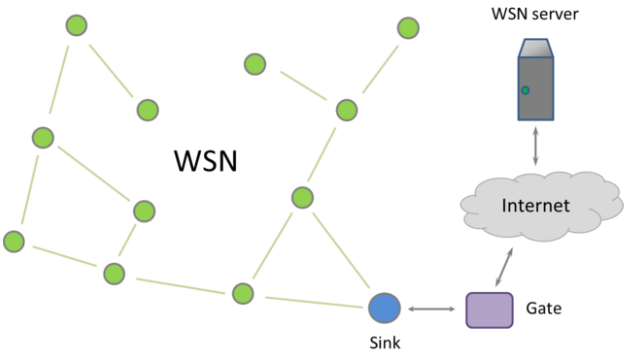

Fig 3: WSN server is connected via the Internet

Gates also make it possible to organize service provision. Nowadays, since access to the Internet via cellular, cable and satellite networks is accessible almost in any place in the world, connection of WSNs to the Internet in most cases is easy to implement. Figure 4 represents the scheme of possible interaction between a user and a WSN.

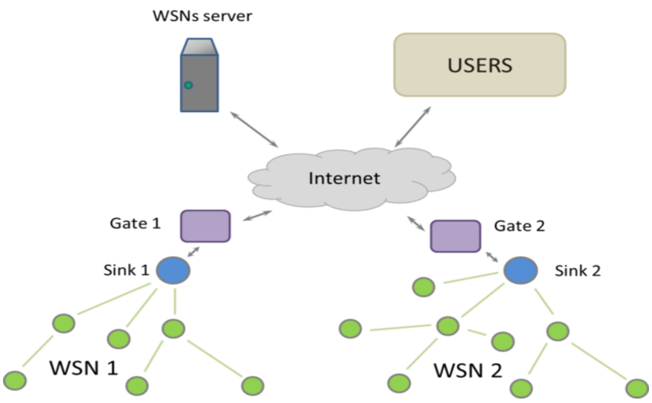

Figure 4: Scheme of provision of WSN services

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IV. Network Topology

➢ **Star**:

The star topology is commonly used in computer networks, so when WSN appeared, it started being used also for arrangement of interaction between sensor nodes. The main characteristic feature of the star topology is connecting of all the sensor nodes to sink directly. Figure 5 schematically represents this topology. In such cases sensor nodes are not connected between themselves, and all interactions among sensor nodes are occurring only via sink. Disadvantage of star topology is limited number of sensor nodes in such WSN. This limitation is present because all the sensor nodes have to be placed in the vicinity of sink, to connect to it directly. Another limiting factor is sink's performance, i.e. the highest number of supported connections.

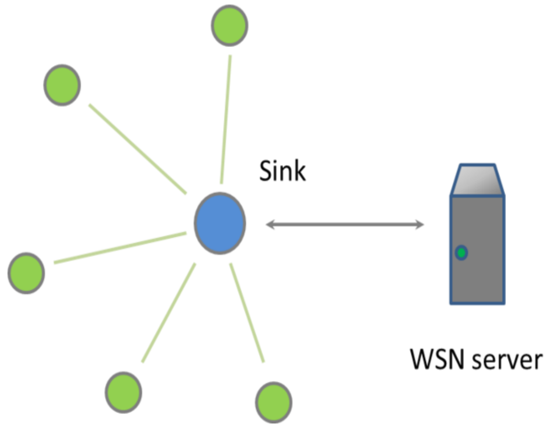

TABLE I. **Figure 5: The star topology**

➢ **Tree:**

The tree topology, in contradiction to the star topology, is much better suitable for WSN with the large number of sensor nodes. It has a hierarchical structure, as it is illustrated on Figure 6. Sensor nodes that are the nearest to sink interact with the sink directly. The more remote sensor nodes interact with the nearest ones according to the rules of the star topology. The tree topology also does not have the provision of direct data exchange between all the sensor nodes. Data transmissions from any sensor node to the sink and in the opposite direction are the only ones allowed. In tree topology, data flow from the levels with greater numbers, called "leaves", can be sent only through the levels with smaller numbers i.e. "roots" and "branches". So, if on the first level there are only three sensor nodes, and the whole WSN consists of ten sensor nodes, traffic will be delivered through these three sensor nodes much longer, because of data retransmission from seven sensor nodes on lower levels. Such a network can fail quickly, because of energy consuming by sensor nodes nearest to the sink.

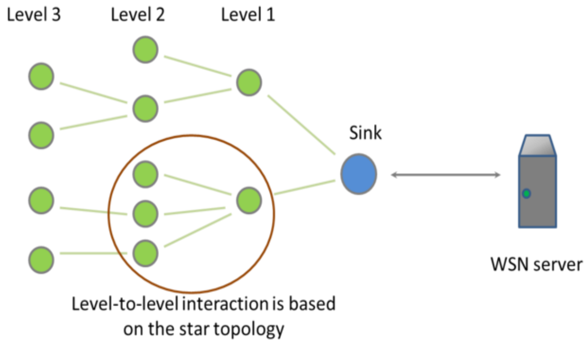

Figure 6: The tree topology

➢ **Mesh**:

The mesh topology is the most complex one for implementation, but it provides much more opportunities for data exchange among sensor nodes. In WSN with the mesh topology interaction within sensor nodes is taking place according to the principle "with every nearest one", as shown on Figure 7. It means that each sensor node cooperates with other sensor nodes, which are in its transceiver's proximity. In such WSN data exchange between sensor nodes passes through the shortest ways and with the smallest number of retransmissions, what has a positive effect on the energy exhaustion of the sensor nodes? [2]

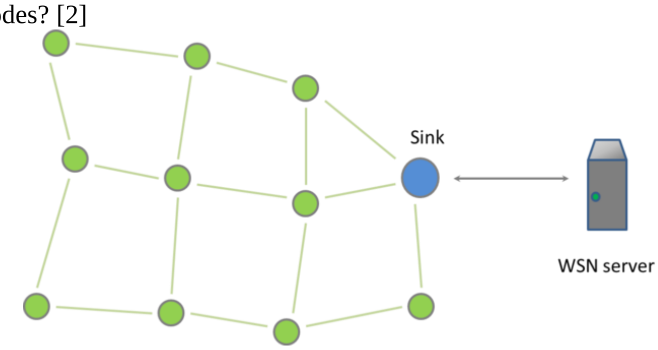

Figure 7: The mesh topology

V. Applications

1. E-Health: There is a wide variety of e-health applications for WSNs. Most of them have been proposed in the last ten years. Some of these applications are: patient monitoring, emergency informing of analysts and emergency services, and offering user-friendly home environment. The majority of e-health applications use WSNs as a part of a complex system which also involves a global communication channel, system of remote processing of collected data and more complex health and rescue systems. General scheme of an e-health WSN-based

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system is shown in Figure 8. Patient is provided with wearable or implantable sensor nodes, which perform continuous measurements of the patient health. Sensor nodes form a WSN, which transmits the gathered measurements to user's mobile terminal. The user's mobile terminal performs measurements processing, result indication and transmitting of the results to the attending doctor using a wide area network.

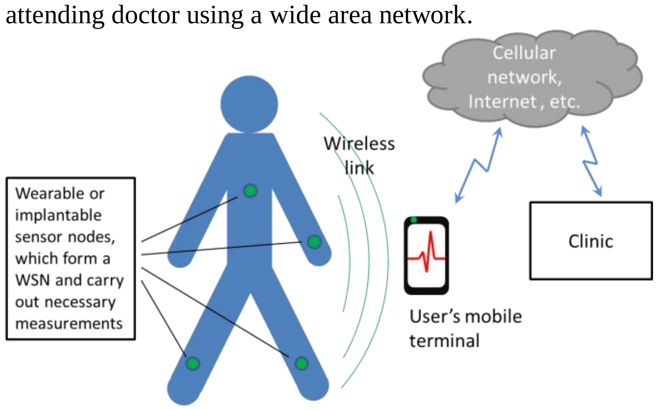

Figure 8: General scheme of e-health system

There are also patient continuous monitoring systems which don't interact with the patient's mobile devices. Such systems are paired with an independent transceiver, running on a dedicated wireless communication channel of the direct link with the clinic. This independent communication channel results travel restrictions, because the patient should be within the range of the used channel. However, such an approach can help to avoid the data loss and unexpected delays by selecting special design techniques for channel planning. The independent communication channel ensures the reliability for e-health system communication, including while global emergency situations when cellular network may be unavailable.

2. Intelligent buildings: Reduce energy wastage by proper humidity, ventilation, and air conditioning control, needs measurements about room occupancy, temperature, air flow, and supervised mechanical stress after earthquakes [3].
3. Agriculture: To monitor vast areas it is necessary to create networks which consist of dozens of thousands of sensors.
The existence of several kinds of measured values (temperature, humidity, chemical composition of the soil) makes it necessary to operate with heterogeneous networks;
Selective irrigation; Fertilizers distribution control; Weeds detecting; Soil mineralization detecting.
4. Home automation: Monitoring of different parameters, such as temperature, turning on the light & opening of locks in rooms; Remote managing of all available in the house systems by the owner: heating, security systems, water supply, air conditioners, home entertainment systems, though the control panel, computer or Smartphone or from any place via the Internet.
Different tasks like protection from criminals, including access control, audio and video surveillance;
Monitoring condition of aged and ill people presenting in the house; Taking care of pets. [4]

VI. Conclusion

Wireless ad hoc networks of battery powered micro sensors are proliferating rapidly and transforming the way information is gathered, processed and communicated. These networks are envisioned to have hundreds of inexpensive sensors with sensing, data processing and communication components. They typically operate in unattended mode, communicate over short distances and use multi hop communication. Many challenges are introduced due to the limited energy, large number of sensors, unfriendly working environment and nature of unpredictable deployment of the sensor network. Energy conservation is found to be the foremost among them since it is often cost prohibitive or infeasible to replenish the energy of the sensors. This energy problem in wireless sensor networks remains one of the major barriers somehow preventing the complete exploitation of this technology. Efficient Energy Management is proved to be the key requirement for the credible design of a wireless sensor network [5].

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