Significance of Satellites in IoT

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Abstract - Internet of Things (IoT) is a system of connected physical objects that are available through the internet. It is used to connected physical devices, vehicles, buildings, and other items with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data. But not any communication device can handle 20 billion connections across different world. Satellite communication system will be critical part in supporting the development of the IoT.

This paper focuses on the use of satellite communication systems to support Internet of Things (IoT). Data are collected from sensors and send control messages to actuators this whole process named as IoT paradigm. In many application scenarios, sensor and actuators are distributed over a very wide area; in some cases, they are located in remote areas where they are not served by earthly access networks and, as a consequence, the use of satellite communication systems becomes of paramount importance for the Internet of Remote Things (IoRT). The factors of IoRT through satellite are:

1) The interoperability between satellite systems and sensors/actuators and
2) The different methods of collecting data

Key Words: Internet of Things (IoT), Internet of Remote Things (IoRT), Machine- to-machine (M2M) communication, Satellite communication, wireless sensor and actuator networks.

1 .INTRODUCTION

Internet of Things (IoT) is a system of associated connected physical objects that are available through the internet. The "thing" in IoT could be a man with a heart screen or an automobile with built in-sensors, i.e. objects that have been allocated an IP address and can gather and exchange information over a system without manual help or mediation. The embedded technology in this article causes them to associate with interior states or the outside condition, which thus influences the choices taken. It empowers devices to watch, distinguish and understand a circumstance or the surroundings without being dependent on human help. [1] As to Gartner report, by 2020 connected devices across all technologies will reach to 20.6 billion. So to handle more than 20 billion devices Satellite technology will be used.

The machine-to-machine (M2M) is a technology at the back IoT. Machine-to-Machine is where "Machines" use network resources to communicate with remote application infrastructure for the purposes of monitoring and control, either of the "machines" itself, or the surrounding environment. M2M is used to provides IoT, the connectivity that enables capabilities, which would not be possible without it. [2] Usually, IoT is expected to offer highly developed connected devices, systems, and services that goes ahead of machine-to-machine (M2M) communications and covers a variety of protocols, domains, and applications.[2]

The M2M communication of the IoT is a very useful and effective aspect of the system. For example, IoT in our own homes to control home security, adjust energy consumption, etc. In the future, our home will likely be called the smart home because of all the components that will use the technology.

Satellite communications have the potential to play an important role for different reasons.

1) First of all, smart objects are often remote or they are dispersed over a wide geographical area or they are inaccessible. We refer to this particular situation of IoT as the Internet of (Remote) Things (IoRT). In IoRT, satellite communication provides a more cost-effective solution with respect to other terrestrial technologies to their interconnection and communication with the "the rest of the world" [3], [4].

2) As mentioned in [5] and [6], group-based communications is a transmission mode that will be important in several IoT and M2M applications where smart objects could be grouped according to the task and/or the information that have to receive. In such a case, network operators should optimize the volume of data to send when IoT/M2M devices need to receive the same message. This kind of applications can be naturally supported via satellite by exploiting broadcast (i.e., toward all nodes of the whole network), multicast (i.e., toward a portion of nodes of the whole network), or geo cast (i.e., toward a portion of nodes placed in a given area of the network) transmissions.

3) In some applications, such as the smart grid, utilities need to implement the highest availability of data communications that is possible within reasonable cost. This requires redundant connections at critical sites. A terrestrial-only redundant approach is not sufficient, as severe disruptions on the ground can disable or destroy both fixed and wireless infrastructures alike, no matter the redundancy. Satellite could provide a true alternative path.

4) Existing IoT/M2M applications generally target low data rate transmission and, hence, current low bandwidth satellite infrastructures can be effectively reused.

As a matter of fact, IoT/M2M communication via satellite is a reality and represents a great opportunity for the satellite market.

2. REAL WORLD APPLICATION WHERE SATELLITE IS A KEY ELEMENT

Before you begin to format your paper, first write and save the content as a separate text file.
There are many applications based on the IoT paradigm [7]. In this section, we select three typical applications of IoRT where the use of the satellite is of paramount importance:

1) Smart grid; 2) Environmental monitoring; and 3) Emergency management. For each specific application, we describe the current and/or the possible future role of the satellite. The objective is to emphasize if current generation of IoRT via satellite can meet the specific application requirements.

2.1 Smart Grid

One of the main efforts toward the implementation of a low-carbon society is the implementation of the smart grid concept [8]. The power grid becomes “smart” when it is able to react and adapt to any event occurring in any point of the grid (generation, transmission, distribution, and consumption) by adopting proper strategies and countermeasures. This capability is fundamental to the following.
Make the power production, transmission, distribution more energy efficient.
Fulfill the growing demand for energy with the same or higher reliability, still keeping low the operational costs.
Provide more transparent services to the user which must play an important role both as consumer and as producer.
To make the smart grid concept a reality, a bidirectional flow of information is needed among the different actors of the grid at different points of it. Many of the elements of a smart grid are already available, including smart meters, automated monitoring systems, and power management systems. The communication network has a crucial role and its cost and performance will greatly influence utilities' revenues and the capability of the new grid to meet its ambitious objectives. For sure, the communication network will be heterogeneous, including wired and wireless segments, and private and public solutions. In this framework, satellite could represent a viable and cost-effective solution in different scenarios, such as the following.
1) Structural and functional monitoring of offshore wind farms or solar energy systems in desert areas.
2) Back-up link when very high availability is required.
3) Remote monitoring and automated control of substations located in remote areas.
As a matter of fact, satellites are already used by utilities in the current grid and also by other types of companies involved in the deployment of renewable energy generation. In particular, M2M via satellite is mainly used today for:
1) Providing back-up links, when high reliability is required and
2) Remote monitoring and automated control of substations located in remote areas.

Table -1: Requirements of Several Functionalities Of The Smart Grid

Functionality	Data rate (kbps)	Latency	Reliability (%)
AMI	<100 (500 kbps for the backbone)	<15 s	<99.99
Demand response	<100	Several minutes	<99.99
WASA	<1500	<200 ms	<99.9999
Distributed generators	<56	<15 s	<99.99

In the existing grid, remote monitoring and automated control of substations is implemented through the SCADA system, which includes several remote terminal units (RTUs) and intelligent electronic devices (IEDs), a master server, and a human–machine interface for the interaction with the human operator [9], [10]. The SCADA master server cyclically queries the operating and status data from the grid. It is usually a low data rate service, low duty cycle, and remote terminals can be geographically dispersed in rural areas.

Therefore, as outlined in [11], a satellite-based solution can provide a cost-effective solution for providing a communication infrastructure to implement SCADA systems, especially in rural areas of the distribution network. Satellite connectivity has been used for years in SCADA applications for remote locations in oil and gas and other energy exploration areas. On the other hand, the current slow central network control based upon SCADA systems is no longer sufficient to implement the new concept of wide-area situational awareness (WASA), which is the use of several types of sensors along the grid to collect data about the state of the grid and by processing these data, being able to act effectively or predict future problems. Moreover, the WASA concept will be heavily based on the wide-area measurement systems (WAMSs) which have the task to collect synchronized measurements from sophisticated sensors, called phasor measurement unit (PMU) with the objective to have an almost real-time monitoring of the grid state [12]. In order to follow almost real-time the dynamics of the grid, measurements from the PMUs should be reported 20–60 times per second. It is worth noting that traditional SCADA systems usually report the data with a frequency that ranges from seconds to minutes. Moreover, latency of the order of 1–2 s is usually accepted in traditional SCADA implementations. Table I shows the main requirements of several functionalities of the smart grid. The WASA concept is definitely more challenging in terms of reliability, latency, and also data rates and the current implementation of M2M via satellite is no longer suitable. But by using several smart grid applications to delivery command to a group of actuator; this also can be refer as group-based communication application will reduce signaling congestion.

2.2 Environmental Monitoring

Health of people and wildlife has been threatened heavily in the last decades. Environmental monitoring aims to enhance the quality of the environment. The use of satellite could be important for the outdoor environmental monitoring in open nature. Outdoor monitoring refers to the detection of the following destructive phenomena: landslides, avalanches, forest fires, volcanoes eruptions, floods, and earthquakes. Such events require fast detection and lead to the need of rapid intervention by first responders (FRs). Furthermore, continuous measurements of air and water pollution, and wildlife position and activity are also included. Wireless sensor networks (WSNs) are well suited for this class of IoRT applications, such as long-term environmental monitoring [13]. However, environmental monitoring poses stringent requirements on the choice of the WSN: large number of nodes, very low cost, eases of deployment, low maintenance, and very long battery duration (possibly using solar energy). Nodes could be highly mobile (i.e., monitoring of wild animals). On the other hand, requirements on communication delay are quite relaxed since this application does not require real-time operation. In this framework, satellites may play a key role, as they would allow covering a wide area, where the satellite terminal could be also highly mobile, without installing a complex infrastructure. As a matter of fact, current M2M satellite systems in L band allows mobile applications such as the wildlife monitoring, where sensors are attached to animals that may move over a very large area. While this low data rate and latency-relaxed application scenario seems pretty "easy" for a satellite-based solution, other challenges arise. For instance, in most of the applications, it is of utmost importance to use very energy efficient protocols, in particular MAC protocols.
Moreover, MAC algorithms must take into account a very variable topology and number of sensor nodes and that number of nodes might be very high. Finally, the operating cost of the monitoring system should be kept low. Therefore, while current M2M satellite systems may support most of the applications, a more effective use of the satellite resources and a proper access to it (via specific multiple access schemes) is needed.

2.3 Emergency Management

Disasters such as earthquakes, fires, floods, explosions, and terrorist attacks may lead to crisis situations which require the intervention of FRs. In order to assist FRs to effectively manage the crisis, emergency response information systems (ERISs) are developed with the aim to provide enhanced situational awareness, automated decision making, and prompt response [14]. Even if the use of existing network infrastructures (PSTN, 2G, 3G, and 4G) is important to connect a disaster site with the external network (crisis center, data bases with emergency plans, hospitals, etc.), the communication infrastructure at the incident area is often only partially available or completely destroyed. In this context, ensuring radio communications for efficient organization of the relief operations is of paramount importance. A possible solution for this lack of communication means is the deployment of ad hoc wireless networks as an incident area network (IAN), i.e., a self-forming temporary network infrastructure brought to the scene of an incident to support personal and local communications among different public safety end-users (fire brigades, police, medics, etc.) and their connection with a gateway [15]. In this context, the IAN can replace the damaged local terrestrial network infrastructure, and, when connected to a satellite network can provide communication with a remote crisis center. This can guarantee the continuity of standard communications (e.g., voice traffic with the crisis center) and allow the exchange of data related to the particular situation, such as data on location of FRs, alert messages, and electronic maps to support FRs during their motion within the disaster area.
An IAN supports both voice and data transmissions and wireless sensor and actuator communications in the local and/or personal area. The approach to the definition of an IAN for emergency management is the following. Every FR is surrounded by wearable and environmental sensors (e.g., vital sign sensor, temperature sensor, structural health sensor, and indoor/outdoor positioning devices) and actuators (alarms and monitors). The FR is provided with a relief member unit (RMU) which is a network node with multi standard capabilities and gateway functionalities. The wireless standards used by the RMU include 6LoWPAN and TETRA. 6LoWPAN allows the communication of the RMU with sensors and actuators, whereas the TETRA network is used for voice/data communications between RMUs within the IAN.
In this case, satellite communication systems allow connecting the IAN to Internet, so that emergency services managed by the Emergency Control Center (ECC) can be provided. In particular, the disaster area and the FRs can be remotely monitored by the ECC and several autonomous monitoring and control functions can be provided through sensors and actuators without the human intervention.

3. METHODOLOGY

3.1 Interoperability

One of the main enabling factors in satellite communications system to support IoRT is the interoperability between satellite and sensors/actuators. As shown in Fig. 1, the satellite collects data measurements from a huge number of sensor nodes and sends it to a ground station for data management. Furthermore, control data are sent from ground stations to the satellite and then to the actuator nodes. Note that, in Fig. 1, we only focus on user data flow without considering signaling/ACK data flow. There are two modes of interoperability between satellite and sensors/actuators: 1) direct access and 2) indirect access. The direct access mode allows sensors and actuators to directly communicate with the satellite, in uplink with the sensors and in downlink with the actuators [16]. In the indirect access mode, each sensor and actuator in a wireless sensor and actuator network (WSAN) may communicate with the satellite through a sink node; therefore, the data flow between the satellite and the WSAN is bidirectional [17]. The advantage of exploiting the indirect access is that a lower number of expensive satellite terminals are required for the same number of sensors/actuators. Furthermore, in the indirect access mode, the sink is provided with a satellite terminal (expensive and power hungry) and with a WSAN radio interface, while all the other nodes of WSAN are only provided with a WSAN radio interface. This solution allows decreasing the system costs and the complexity of the installation (in terms of antenna pointing and power generation facilities). However, this approach has the typical drawbacks of a centralized solution with respect to a decentralized solution. In current M2M via satellite systems, most of the protocols are proprietary and/or are not designed to support Internet protocols.

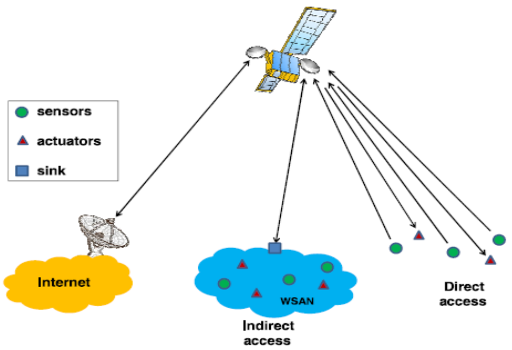

Fig -1: satellite system communicating with sensors and actuators.

3.2 Satellite-Routed Sensor System (SRSS)

In the wireless communication area, several kinds of development such as ZigBee, Bluetooth, WI-Fi, and Near Field Communication (NFC) are considered as candidates to communicate with these things. However, there remain many areas where the afore-mentioned network services have not yet covered. Moreover, since the network capacity is limited, it is difficult to manage numerous things and to realize concurrent access. As a consequence, we focus on a data collection technique by using the Satellite-Routed Sensor System (SRSS), which is expected as a next generation technology to efficiently collect data from wireless sensor terminals [18].

In the SRSS, a satellite collects data from sensor terminals and sends the data to ground stations, which manage the data from these sensor terminals as depicted in Fig. 2. By using the satellite, it is also possible to collect data from areas with inadequate network infrastructures (e.g., disaster stricken areas) where the ground network facilities were damaged/destroyed [19], [20]. In addition, since the satellite network is superior in terms of simultaneous communication, numerous sensor terminals are able to access the network at the same time [21]. Thus, the SRSS offers a promising solution to realize IoT efficiently and therefore, can help construct the smart society. However, in an environment where a huge number of sensor terminals are attached to many kinds of things such as cars, homes, and buildings, and send data at any time to the satellite, data collisions may occur at the satellite. Therefore, an efficient access control method is necessary for the system.

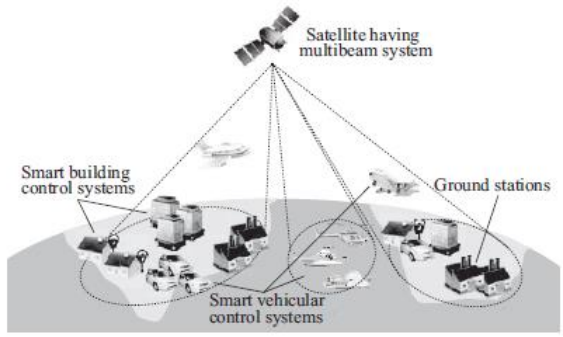

Fig-2: An example of an SRSS used for facilitating the IoT.

3.3 Access control method:

3.3.1 Carrier Sense Multiple Access/Collision Detection (CSMA/CD) and Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)

Random access in SRSS for efficiently and flexibly collecting data is needed to facilitate communications between numerous sensor terminals and a satellite. Since the random access causes collisions of data at the terminals receiving the data, many access control methods are developed such as Carrier Sense Multiple Access /Collision Detection (CSMA/CD) and Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) for the common terrestrial networks. However, since many things attached with sensor terminals are deployed over a wide area and they communicate with the same satellite in the supposed network environment, the distance between these sensor terminals is significantly long to detect radio waves from the neighboring sensor terminals.

3.3.2 Contention-based and fixed assignment schemes

The conventional access control methods are classified into two groups, contention-based schemes and fixed assignment schemes. As a contention-based scheme, ALOHA [22] is a

famous method used in the satellite networks. In the case where ALOHA is used, upon data generation, each terminal on the ground sends the data to a satellite. If collisions occur at the satellite due to the data received from multiple terminals, each terminal waits for a random time and then resends the data. By using the random waiting time, the terminals can avoid further collisions. Moreover, slotted ALOHA, which is developed by improving the ALOHA is also a general method using random access control. In the slotted ALOHA technique, each terminal is controlled to send the data at a regular interval in contrast with ALOHA, which permits each terminal to send its data at any time. By controlling the sending time, the slotted ALOHA avoids retransmissions which occur due to the data collisions. Thus, the slotted ALOHA achieves higher throughput than that in ALOHA. On the other hand, Time Division Multiple Access (TDMA) is well known as a fixed assignment scheme. In TDMA, the terminals are allocated time-slots (which are the smallest logical units for bandwidth allocation) and send their data during the time-slots by rotation. Since each sensor terminal can send data at different time instants with regular intervals, it is possible to avoid the collisions caused by the overlapping of the timing of data sending.
However, in the case where numerous terminals are deployed that leads data generation at any time, the performance of these conventional methods decreases drastically. In the case of ALOHA and slotted ALOHA techniques, the increase of the number of terminals causes the increase of probability that more than one terminal send data to a satellite at the same time. As a result, continuous collisions might occur and it causes the decrease of the throughput performance

3.3.3 Divide and conquer approach

Here data will be collected on demand efficiently from the sensor terminals, which have some data, to send to numerous other terminals with a significantly small operating time. The satellite collects data from the sensor terminals on-demand by a "divide and conquer" approach to avoid ineffective bandwidth allocation. Fig. 3 shows the example of the process-flow of this method in case that there are thirty two sensor terminals. In this method, the satellite repeats to divide the sensor terminals into some groups for distinguishing the terminals having data to send. This step is called the searching phase. Each group
G(D,i)(α, β) in Fig. 3, shows a group, consisting of sensor terminals that have identification numbers ranging from α to β, where D and i indicate the number of dividing (or division) processes and the group ID after the dividing is conducted D times, respectively. By the end of every searching phase, each identified sensor terminal will have a time-slot allocated. After repeating the dividing process several times, the satellite stops dividing the sensor terminals into groups and allocates time-slots to all the remaining sensor terminals by using TDMA, regardless of them having data to send or not, to decrease the total operation time. By allocating time-slots to all the remaining terminals regardless of them having data to send or not, this method can avoid unnecessary time for confirming the existence of data in the sensor terminals' buffer.

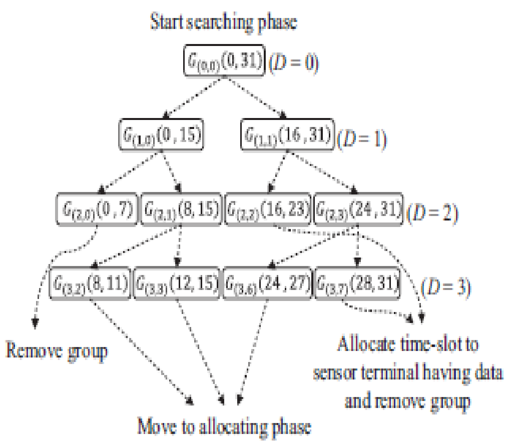

Fig-3: An example of the flows to divide a number of sensor terminals into some groups (like a binary partition tree).

4. CONCLUSIONS

This paper provides an overview of satellite communication system in view of its use in IoRT application scenarios. There is no much research particularly concentrated on the use of satellite to IoRT situations and there is no genuine consciousness of the potential preferences originating from their utilization later on IoRT situations, regardless of the possibility that they as of now assume a vital part in a few M2M correspondence applications nowadays.
In order to realize the IoT all over the world, providing network environment not only to urban areas but also to areas lacking adequate infrastructure (e.g., disaster-affected zones, rural areas, and so on) is essential. In this paper, we focused upon using satellites to communicate with many things i.e. IoT.
Toward this end, we proposed some methods used collect data efficiently from an arbitrary wide area in the IoT by means of SRSS.

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