IJCSEC- International Journal of Computer Science and Engineering Communications.
Vol.3, Issue 2, 2015, Page.870-880, ISSN: 2347–8586

Wlan Power Save with offset Listen Interval for Machine to Machine Communications

Prakash.T
Department of Computer Science and Engineering,
Erode Sengunthar Engineering College, Erode. India
Email:mohanesec328@gmail.com

ABSTRACT: M2M communication networks have the cost and energy efficiency problem of the embedded devices. Wireless LAN power save mechanism is designed to experience the performance degradation and also unbalanced energy consumptions in the human communication systems. An analytical model takes into account for a different network architecture and traffic patterns of the communication between the machines. And, the model ensures the high contention and long packet delay found during the process of packet forwarding in the network. To minimize the performance drop, a new algorithm called Offset Listen Interval (OLi) is proposed which enriches the existing power save mechanism and increases the life time of communication networks. The algorithm extends the traffic occurred in the M2M systems with calculated offset to improve the network contention and to reduce packet delay. OLI defines energy efficiency and compares it with the standard power save mechanism. The Orthogonal Frequency Division Multiplexing (OFDM) algorithm is proposed that requires only one received OFDM block and it belongs to the category of one-shot estimation method.

1. INTRODUCTION

M2M communication is different from current Human-to-Machine (H2M) and Human-to-Human (H2H) communication models in that it involves new or different market scenarios, low cost, low power, low effort, a potentially very large number of communication terminals, and infrequent data transmissions per terminal. The current wireless networks are mainly designed for H2M and H2H communication modes based on mobility and human interactive requirements such as c all setup, handover, and quality of service (QoS). Since M2M communications bring very different network structure, devices, traffic patterns, and performance requirements, there are urgent needs to enhance the wireless access networks for M2M communications. In fact, there are potential issues of high contention and unbalanced power consumption that may hinder large scale deployment of M2M communication networks. In a M2M communication network, there can be a large number of STAs associated with one AP. The traffic from these STAs includes sensor/meter readings in the uplink and actuation/control messages in the downlink. This traffic is expected to be light and periodic with a predefined ListenInterval in the order of minutes. When the ListenIntervals of a number of STAs are aligned, i.e. they wake up in the same beacon period to poll the AP, high collision may arise even when the overall network traffic load is low. The process result shows that the network collision probability and packet delay can be as high as 30% and 16 ms, when there are 15 stations polling in one beacon period.

Analytical model is to characterize the power save performance of contention based M2M communication networks with large numbers of devices and periodic traffic. The model predicts the collision probability and packet delay of a M2M communication device. Analysis results show high collision probability and long delay associated with M2M PS devices, while traditional traffic models under estimate such measures. Algorithm is used that spreads the M2M traffic evenly across WLAN beacon periods with calculated offsets to alleviate network contention and reduce packet delay. The algorithm used is Offset ListenInterval (OLi) algorithm.

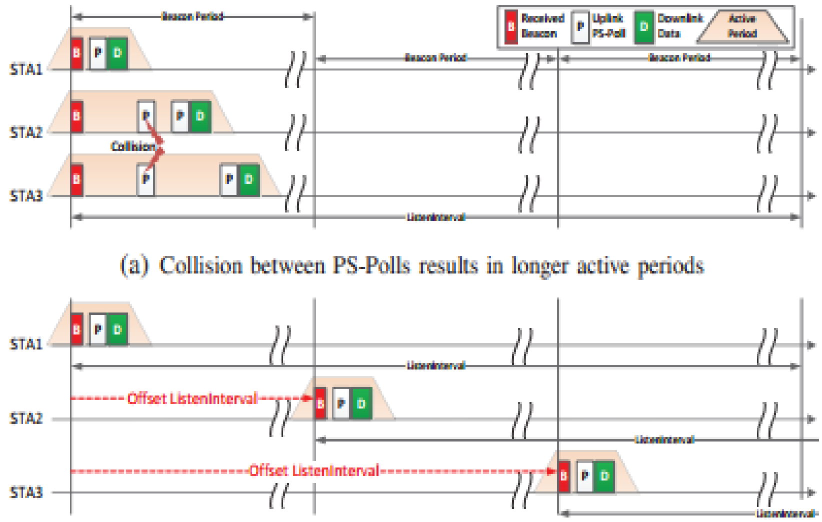


Fig 1.1 Collisions between PS-Polls

The OLi algorithm is designed as an enhancement to the standard PS mechanisms to extend the lifetime of M2M communication networks. Use the analytical model to evaluate the energy consumption and network lifetime of proposed OLi algorithm working in conjunction with and enhancing existing PS mechanisms. Analyses shows that OLi is able to extend network lifetime by up to 40%, or 1 year, compared with standard PS mechanisms. Our results demonstrate that the proposed OLi algorithm is able to scale up to thousands of nodes for a M2M communication network.

Paging Operation

Group paging is a mechanism for reducing a paging overhead and may be used for the purpose of multicast traffic indication, requesting a group of users to perform network re-entry updating the group control parameter (e.g., paging cycle, paging offset, etc). X is included in a paging message instead of an individual identifier to identify the group of M2M devices.

When the M2M device receives the group paging message during the paging available interval, it can perform the following procedures:

- Perform the network re-entry: when the M2M device receives the group paging message which includes the identification of its M2M group to be notified of requesting the network re-entry, it shall perform the network re-entry. If the M2M device receives the group paging message which does not request the network re-entry, it shall not perform the network re-entry.
- Receive the multicast traffic: when the M2M device receives the group paging message which includes the identification of its M2M group to be notified of pending DL multicast traffic, it shall receive the multicast traffic.
- Update control parameters: when the M2M device receives the group paging message which includes the identification of its M2M group to be notified of updating the control parameters, it shall update indicated control parameters in the group paging message.

An M2M Group Identifier (MGID) and an M2M Device Identifier (MDID) are used to indicate an M2M group and each M2M device within the M2M group. An M2M Group Identifier and an M2M Device Identifier are unique within the paging group of M2M device. An M2M Group Identifier (MGID) and an M2M Device Identifier (MDID) shall be assigned to an M2M device during the network entry. The paging group ID is assigned to an M2M device during the idle mode initiation through AAI-DREG-RSP message. The ABS shall advertise the paging group ID (PGID) in the PGID-Info message.

Network re-entry from idle mode for M2M devices

In order to reduce network congestion produced by a large number of M2M devices, network re-entry from idle mode procedure for M2M devices should be based on group. After a M2M group is established, BS should allocate a ranging code set to M2M groups based on M2M group ID. When a M2M group is expected to report their data, a group member which is a delegate of the M2M group sends a ranging code from the above ranging code set to BS.A M2M device in a M2M group is called as a group member (GM).The GM which sends the ranging code is called as group delegate (GD).This ranging code is called as GDC (group delegate code). After BS decoded this ranging code, BS sends AAI-RNG-ACK to respond to this ranging code, which includes three ranging status (success, abort and continue).

2. LITERATURE SURVEY ON EXISTING SYSTEMS

2.1 MACHINE TO MACHINE TECHNOLOGIES

Matt Cullinen et .al (2011) The communications industry has proven to be one of the bright stars of the high-tech economy, demonstrating an almost endless capacity for adaptation and innovation. The industry has completely transformed itself from one dominated by businesses centred on landline phone services to one supporting diverse portfolios, with mobile capabilities and digital offerings spanning from telephony to internet connectivity and beyond. M2M Drives the Development of new Products and services that this rapid expansion of products and services represents a global technological revolution is undeniable today 87 percentage of the world's population have mobile cellular telephone subscriptions, and 34 percentage have home internet access leveraging wireless connectivity and a variety of iCt solutions in order to increase business efficiency is already common place in global business, as both big firms and small to medium-sized enterprises have recognized that using these time- and cost-saving technologies to support a more mobile or virtual workforce is critical to maintaining a competitive advantage in their markets. For example, between 42 percentage and 47 percentage of firms are currently expanding their support for employee mobile connectivity, primarily by investing in handheld devices, smartphones, and tablets, while 31–33 percentage of firms are taking even further steps to develop corporate mobility strategies and policies yet until recently, despite the ubiquity of cellular and WiFi, this connectivity was entirely human focused, it connected people to information or to other people.

'Machine-to-Machine' (M2M) technologies [2] represent an entirely new paradigm of connectivity. M2M connects machines to machines, and no human intervention is required to communicate, process, or even act upon the information the machines are collecting and sharing.M2M makes it possible to map and monitor an entire system of remote hubs, which could be anything from a building to a vehicle, or a vending machine to a factory's welding arm in real time. The core capabilities of M2M in any application are to reduce human error, save time, increase efficiency, conserve resources, and generally optimize the performance of a physical system. The term 'M2M',which is also commonly known as 'ubiquitous' or 'pervasive' computing refers to what is essentially a four-step process: data is generated, data is transmitted, data is analyzed and data acted upon a M2M system, digital microprocessors and sensors are embedded into everyday objects in order to generate data about the functions of those objects or their environments.

The objects are also connected to high-speed and high-capacity data transmission networks, usually wireless and can therefore instantly transmit the data collected by their sensors to a computer capable of very rapidly analyzing that data in order to extract meaningful information. If needed, the computer can then transmit instructions back to the object in order to optimize its functionality based on the data received.M2M requires a broad range of technologies, including machines, sensors, networks, custom analytics software and the back-end it infrastructure of many operations. While some aspects of M2M technology have existed for many years, wireless connectivity only recently increased in power and declined in price to the extent needed to allow for the wide spread implementation of M2M.These advances in wireless capabilities came on the heels of other recent advances in sensors and technologies such as GPs, as well as in computing power and data processing all of which M2M systems make use.

2.2 M2M: FROM MOBILE TO EMBEDDED INTERNET

Geng Wu et .al (2011) Machine-to-Machine (M2M) communications in the context of the mobile Internet has been a subject of intense discussions. Some see it as the next technology revolution after the computer and Internet. Part of the confusion has been that M2M is not something completely new [3]. For those familiar with embedded control, M2M is a natural extension of their existing business. They fail to see the explosive growth that others are excited about. Other people also remember the high-tech bubbles in recent history, and question the practical future of M2M.Intel recently completed an extensive study on the issues critical to the M2M industry. Exchanged views are used with leading equipment manufacturers, software vendors and service providers. Several M2M use cases that offer significant market potential. Discuss the requirements and challenges associated with mass-scale M2M networks, and describe potential system architectures and deployment options that can enable the connectivity of billions of low-cost devices. The salient features of M2M traffic are described that may not be supported efficiently by current standards and provides an overview of potential enhancements. Finally, summarize the progress of standards development for M2M.

Multiple connectivity options are available today to connect M2M devices to a server and each other. However, to do this on the scale of billions to trillions, particularly when many devices are limited in range due to cost/size/power constraints, hierarchical deployments that provide reliable, efficient interworking between multiple communication protocols (PAN/LAN/WAN) will be needed. Figure 1 captures a high-level view of a hierarchical M2M system architecture. The M2M device can connect to the M2M server directly through a WAN connection (e.g., cellular 3G/4G) or an M2M gateway (aggregation point).The gateway is a smart M2M device that collects and processes data from simpler M2M devices and manages their operation. Typically, connecting through a gate-way is preferred when devices are sensitive to cost, power, or location. There are several lower-cost radio protocols, such as IEEE 802.11, IEEE 802.15 and power line communications, through which these devices can communicate. Many M2M applications will require connectivity between end devices. Peer-to-peer (P2P) connectivity can be supported in this architecture at various levels of hierarchy depending on latency requirements and the type of information exchanged.

2.3 EFFECTIVE MACHINE TO MACHINE COMMUNICATIONS IN SMART GRID NETWORKS

Deepak Puthal et .al (2012) The main deficiency of the smart grid communication technology is to real time monitoring the data and sends this data to the control centre which is far away from the monitoring area. Transforming the current grid into a dynamic, resilient, and adaptable Smart Grid will be one of the biggest technological challenges of this time. Main issues are like communication delay, cost effective, real time monitoring and security. This work is mainly focus on implement the smart grid network to reduce the cost and low latency with considering the existing network technology. There are three networks such as building area network (BAN), neighborhood area network (NAN) and the wide area network (WAN).

In the BAN data is going to be collect by the ZigBee network. Concentrator node work as the gateway node and sensors mingle with the home appliances which are used to sense the consumed voltage by the equipment. Our basically focus is on the machine to machine communications in BAN. In the NAN all the gate way are going to transmit there data to the GSM base station sometimes it have taken as the WiFi network to communicate with base station. The base station is going to transmit the data to the control centre through the public internet. Main focus to design this network is to reduce the cost and low latency. In case of traditional wire line network cost is very high and more complex one. It proposed a new concept on wireless technology for low latency critical data transmissions.

Communication Requirement for Smart grid

Communications requirements of power grid and other entities involved in the generation, transmission and distribution of electricity will inform the development of the nation's Smart Grid policies. Smart grid has many new applications for consumers, suppliers, utilities and others and it will be composed of many vast, interrelated systems. One of the key technology areas of the Smart Grid is integrated two-way communications, which allows for dynamic monitoring of electricity use as well as the potential for automated electricity use scheduling. Many communications and networking technologies can be used to support Smart Grid applications, including traditional twisted-copper phone lines, cable lines, fiber optic cable, cellular, satellite, microwave, WiMAX, power line carrier and broadband over power line, as well as short-range in-home technologies such as WiFi and ZigBee. In this paper we compare different technology for energy conservation. The Smart Grid applications that might be built on such communications technologies include Neighborhood Area Network (NAN), Home Area Networks (HAN) and Building Area Network (BAN), enhanced substation Supervisory Control and Data Acquisition (SCADA) system distributed generation monitoring and control demand response and pricing systems and charging systems for plug-in electric vehicles.

Smart Energy Demand

Smart energy demand describes the energy user component of the smart grid. It goes beyond and means much more than even energy efficiency and demand response combined. Smart energy demand is what delivers the majority of smart meter and smart grid benefits. Smart energy demand is a broad concept. It includes any energy-user actions to:

- Enhancement of reliability
- Reduce peak demand
- Shift usage to off-peak hours

2.4 GRS: THE GREEN, RELIABILITY AND SECURITY OF EMERGING MACHINE TO MACHINE COMMUNICATIONS

Rongxing Lu et .al (2011) The exponential growth of wireless communication devices and the ubiquity of wireless communication networks have recently led to the emergence of wireless machine-to-machine (M2M) communications as the most promising solution for revolutionizing the future "intelligent" pervasive applications [4]. The primary advantage of M2M communications is that many intelligent wireless devices may act as "servers" collaboratively collecting and delivering real-time monitoring data to people. Since it does not need direct human intervention, M2M communications is fast becoming a market-changing force for the next-generation intelligent real-time networked applications.The best known application of M2M communications is probably the satellite navigation system, which enables the transferring of up-to-date traffic information and relevant useful location information to drivers on the road. In the near future, M2M communications can be used to more efficiently monitor the conditions of patients, environmental resources, and so on. Many promising real-time monitoring applications including e-healthcare, smart homes, environ-mental monitoring, and industrial automation can be revolutionized by the emerging M2M communications. Despite the promising real-time monitoring applications and tremendous benefits, M2M communications is still in its infancy and faces many technical challenges. These challenges include M2M deployment architecture, M2M software and M2M communications energy efficiency, reliability and security the energy efficiency, reliability and security issues in M2M communications have not been well explored. According to a recent report on global carbon emissions, information and communication technology (ICT) accounts for 2–2.5 percent of all harmful emissions, which is almost equal to the global aviation industry. Therefore, to protect global environments, green communication has been widely advocated for achieving energy efficiency in communication networks. As a pervasive ICT, M2M communications, which encompasses a mass of intelligent wireless devices, obviously should satisfy the energy efficiency requirement.

Here technically discuss the energy efficiency, reliability and security issues in emerging M2M communications, aiming to provide an energy-efficient, reliable and secure M2M communications environment.

First give a high-level overview of M2M communications architecture and its GRS requirements. Then address energy efficiency in M2M communications by introducing an efficient activity scheduling scheme for energy saving. Monitor reliability and security in M2M communications, and discuss several approaches to offer a reliable and secure M2M communications paradigm. It provides conclusions on M2M communications with guaranteed GRS and the potential research issues.

2.5 RECENT PROGRESS IN MACHINE-TO-MACHINE COMMUNICATIONS

Rose Qingyang Hu et .al (2011) Machine-to-Machine (M2M) communications is a new technology that leverages these networks to bring smart services to a much wider audience. Different from the traditional Human to Human (H2H) communications for which the current wireless networks are designed and optimized, M2M communications is seen as a form of data communications between entities that do not necessarily need any form of human intervention [5]. It is different from current communication models in the sense that it involves new or different market scenarios, low cost and low effort, a potentially very large number of communicating terminals and small and infrequent traffic transmission per terminal. The industry has already been working on providing M2M communications and smart services offerings across a wide variety of market segments, including healthcare, manufacturing, utilities, and distribution and consumer products. Smart services are the new services and business models enabled by M2M capabilities. For example, smart grid technology enables utility providers to wirelessly connect to their grid assets such as circuit breakers, transformers and other sub-station equipment. This wireless monitoring capability allows them to develop interactive utility networks that are more intelligent, resilient, reliable and selfbalancing.M2M communications or machine-type communications(MTC) as sometimes referred by the Third Generation Partnership Project(3GPP) is enabling an ubiquitous computing environment toward the pervasive Internet.

2.6 HOME M2M NETWORKS: ARCHITECTURES, STANDARDS, AND QOS IMPROVEMENT

Yanzhang et .al (2011) Home networks are rapidly developing to include a large diversity of devices/machines/terminals including mobile phones, personal computers, laptops, TVs, speakers, lights and electronic appliances. With the dramatic penetration of embedded devices, Machine-to-Machine (M2M) communications will become a dominant communication paradigm in home networks, which currently concentrate on machine-to-human or human-to-human information production, exchange and processing. M2M communications is characterized by low power, low cost, and low human intervention. M2M communications is typically composed of a number of networked devices and a gateway [9]. The gateway is responsible for the connection among the devices and the connection between the M2M communications area and other networks (e.g., the Internet). The M2M network may use an appropriate standardized radio technology based on the requirements of a specific application. From the data management perspective M2M communications consists of three phases: data collection, data transmission and data processing. The data collection phase refers to the procedure used to obtain the physical data. The data transmission phase includes the mechanisms to deliver the collected data from the communications area to an external server. The data processing phase is the process of dealing with and analyzing the data and also provides feedback on how to control the application. Machines are normally small and inexpensive which puts several constraints in M2M communications including energy computation, storage and bandwidth. These constraints pose a number of unique challenges in the design of home M2M networks to achieve a highly connected, efficient and reliable home.

Interference

S.NO	Title	Techniques	Advantages	Disadvantages

There is ever more intensive interference with more radio systems in home areas, including unlicensed systems operating in the industrial, scientific and medical(ISM) frequency band, electronic equipment and domestic appliances. The performance of M2M communications may be seriously degraded due to such self-existence/coexistence interference.

Channel Dynamics

Wireless channels in M2M communications are notoriously unreliable due to channel fluctuations and noise, which may become even worse due to the complicated construction in an indoor environment.

Resource Constraints

The machines may be resource constrained with respect to computation, storage, bandwidth and power supply. There is always an essential trade-off between energy, reliability, and flexibility due to resource constraints.

2.7 TOWARD INTELLIGENT MACHINE-TO-MACHINE COMMUNICATIONS IN SMART GRID

Zubair Md. Fadlullah et .al (2011) Smart card is widely predicted to see the rise of Machine-to-Machine (M2M) communications over wired and wireless links. For instance, researchers predict that by 2014 there will be 1.5 billion wirelessly connected devices that are not mobile phones and do not require any human intervention. This will lead to an increase in data traffic involving machines communicating with other machines without human interaction. Various applications of M2M have already started to emerge in various sectors such as healthcare, vehicular, smart home technologies and so forth. The evolution of M2M has also begun in developing a smart power grid framework, referred to as the smart grid (SG) [10]. An electric grid having smart capability allows the power providers, distributors and consumers to maintain near-real-time awareness of one another's operating requirements and capabilities. Through this awareness, SG is able to produce, distribute and consume power in the most efficient and intelligent way. This type of communication takes place only among machines such as sensors, smart meters and other equipment. The M2M communication in SG must be private and secure since many of the autonomic functions that will run over it will be critical.SG will have numerous electrical appliances connected to one another in a complex manner so that they can report back on elements such as power consumption and other monitoring signals. This promises higher efficiency in the power distribution networks (i.e., greater availability of power to homes and factories at lower cost) and will allow distributed power generation such as local solar and wind generators. It will reach into home-based devices, which is why scalability and fast communication is crucial for practical deployment of SG.

2.8 TOWARD UBIQUITOUS MASSIVE ACCESSES IN 3GPP MACHINE-TO-MACHINE COMMUNICATIONS

Shao-Yu Lien et .al (2011) Wireless personal communications have been widely applied to exchange voice, audio, video emails, photos and more among individuals. Such demands of ubiquitous communications among humans thus drive the development of abundant advanced wireless technologies and systems such as the Cognitive Radio Network (CRN) and Third Generation Partnership Project (3GPP) Long Term Evolution-Advanced (LTE-Advanced) [8]. In addition to Human-to-Human (H2H) communications, an emerging technology empowering full mechanical automation (e.g., the Internet of Things and the smart grid) that may change our living styles is vigorously being developed. Such communications among machine-type communications (MTC) devices are known as Machine-to-Machine (M2M) communication. To enable full mechanical automation, three major classes of communications shall be involved.

1	Machine to Machine Technologies	'Ubiquitous' or 'Pervasive' computing	High-speed and high-capacity data transmission	Computing power and data processing is slow
2	M2M: From mobile to embedded internet	Embedded mobile Internet	Efficient interworking between multiple communication protocols services	Difficult to maintain Connections
3	Effective machine to machine communications in smart grid networks	Smart grid communication technology and ZigBee network	Energy efficiency and demand response are high	Network cost is very high and more complex
4	GRS: The green, reliability and security of emerging machine to machine communications	Information and communication technology	Provide an energy efficient, reliable and secure M2M communications	Harmful emissions are involved
5	Recent progress in machine-to-machine communications	Machine-type communications and Third Generation Partnership Project	High quality of service and high reliable	Load balance and fault tolerant
6	Home m2m networks: architectures, standards, and QoS improvement	Standardized radio technology	Low power, low cost, and low human intervention	Channel fluctuations and noise
7	Toward intelligent machine-to-machine communications in smart grid	Communications over wired and wireless technology	Higher efficiency in the power distribution networks	Delay in packets Transmission
8	Towards ubiquitous massive accesses in 3gpp machine-to-machine communications	Cognitive radio network and Long Term Evolution	Enable full mechanical automation	Difficulties in satisfying the requirements

Table 2.1 Comparative Study

Communications between the sensor and the decision maker

Meters/sensors report the measured data to the decision maker.

Communications among multiple calculation agents within the decision maker

The decision maker may comprise multiple calculation agents. Based on the measured data, the decision maker may perform the decision making calculations by leveraging

3. IMPLEMENTATION

The system consists of four modules and they are as follows,

- Uplink and Downlink Control
- Increase in Network Life Time
- Power Save Mechanisms
- Offset Listen Interval Algorithm

3.1 Uplink and Downlink Control

There are potential issues of high contention and unbalanced power consumption that may hinder large scale deployment of M2M communication networks. In a M2M communication network, there can be a large number of STAs associated with one AP. The traffic from these STAs includes sensor/meter readings in the uplink and actuation/control messages in the downlink. This traffic is expected to be light and periodic with a predefined Listen Interval in the order of minutes. A STA wakes up to listen to the beacon once every listen interval (ListenInterval) and if available, polls the AP to retrieve its buffered data.

3.2 Increase in Network Life Time

The lifetime of a STA is the time until the STA runs out of energy. The lifetime is inversely proportional to its energy consumption rate. Let LAPSD(N) and LPSMP(N) denote, for an APSD and PSMP network respectively, the expected lifetime of a STA that is in a beacon period containing N STAs. Then, LAPSD (N) and LPSMP (N) are in years. The network lifetime is defined as the timespan from a network's deployment to the instant when the network is considered non functional, e.g. less than some percentage of nodes remain functional and should calculate the life time of every link and every path.

3.3 Power Save Mechanisms

Develop a new analytical model of IEEE 802.11 power save that takes into account the specific network composition and periodic traffic pattern of M2M communication networks. In particular, analyze the contention behaviour of APSD within a beacon period, where there are potentially multiple STAs waking up simultaneously and competing to retrieve their packets.

3.3.1 Packet Delay

The network counts can have different durations as follows: when no STA is transmitting, the duration is a slot time, denoted by σ; when a collision occurs, the duration is T_c; and when a successful transmission in made, the duration is T_s. Denote by P_T (k) the probability of a transmission attempt by a particular station at network count *k*, such that:

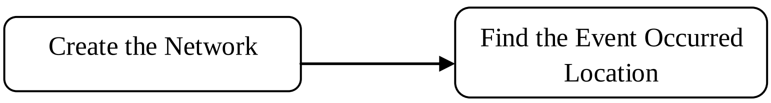
$$P_T (k) = \sum_{i=0}^{s} T_{i+1,k}$$

For each network count, there are different possible combinations of stations transmitting or not.

3.4 Offset Listen Interval Algorithm

OLi can be seen that as the number of competing STAs within a beacon period is increased, the average collision probability and average delay will increase for all STAs within the beacon period. The increase in delay is faster than linear, so as well as the particular STAs involved suffering longer delays, the overall average delay for all the STAs in the network will also be longer. Such increase can be significant. In OLI, the AP maintains a Beacon Occupancy Table (BOT) which records the number of power saving STAs scheduled.

The model illustrates high contention in power and packet delay in machine to machine communication. Propose a new technique to overcome the power consumption and it extends the lifetime of the machine communication. Standard WLAN power save mechanisms, which are designed for human communications, experience performance degradation and unbalanced energy consumptions in M2M communication networks. A novel analytical model is designed that takes into account the fundamentally different network architecture and traffic patterns of M2M communications. The OLi algorithm spreads the M2M traffic evenly with calculated offsets to alleviate network contention and reduce packet delay.



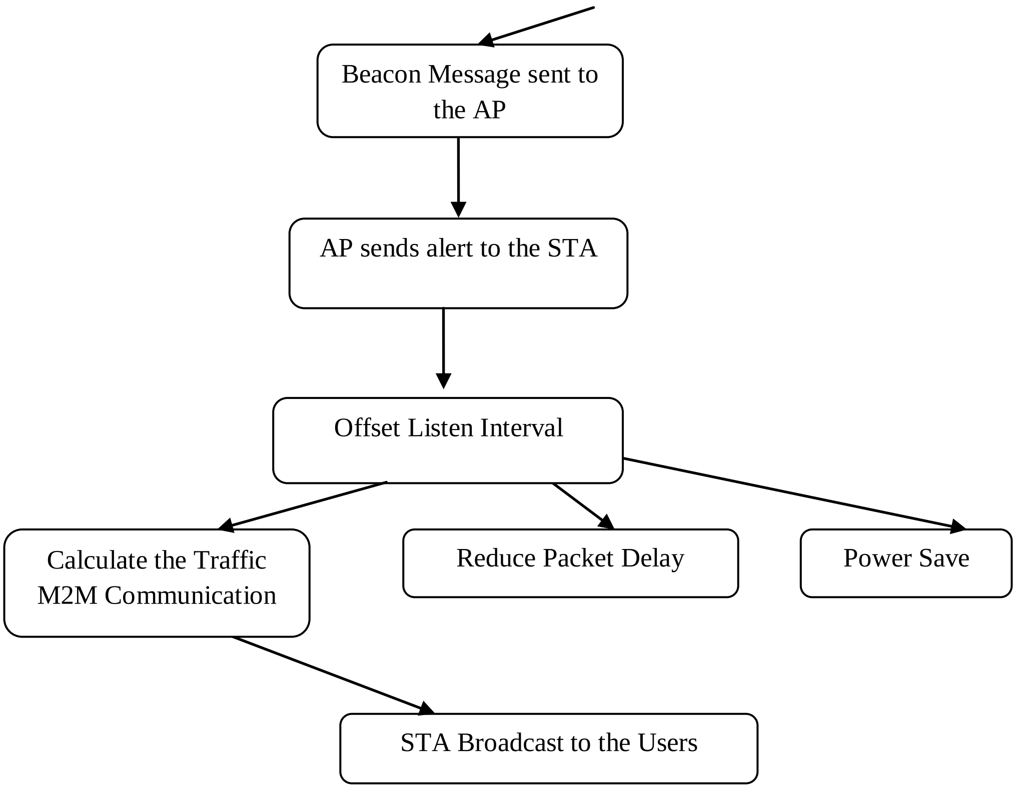


Fig 3.1 The overall flow diagram

4. CONCLUSION

An analytical model is developed to characterize the power save performance of M2M communication networks with a large number of nodes and periodic traffic. The analytical model revealed high contention and long packet delay in M2M communication networks. To address such performance issues, designed the OLi algorithm that enhances standard PS mechanisms to extend the lifetime of 802.11ah M2M communication networks. OLi alleviates the contention and reduces packet delay of the STAs by controlling their wake up times with calculated offsets. The analytical model was then used to evaluate the energy consumptions of the proposed OLi-enhanced PS mechanisms namely, A-OLi and M-OLi. Our results demonstrate that, compared with standard PS mechanisms, OLi extends the lifetime by up to 40% or 1 year and scales up to thousands of nodes in an IEEE 802.11ah M2M communication network. Although M-OLi achieved marginally higher lifetime than A-OLi, the scheduled transmissions in M-OLi are difficult to implement in practice.

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