Priority based solution approach with Uniformly WiGrid Configurations in Smart Grid Communications

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Abstract- WiMAX (Worldwide Interoperability for Microwave Access) is a wireless broadband technology, which supports point to multi-point (PMP) broadband wireless access. There are various research works done to approach WiMAX in Smart Grid technology and they termed as WiGrid. These works aim to achieve all the requirements that Smart Grid require. Various configurations such as frame duration, type-of service to traffic mapping, scheduling strategies are modified to fulfill Smart grid communication. However, the proposed protocol priorities base station alone. The selection of various scheduling types is applied only to Base station within the network. However, this priority-based selection is not considered in other types of equipment such as relay stations, fixed station, consumer premise equipment etc. This paper is to propose a new protocol which studies the features of WiGrid by applying in all types of devices within Smart Grid.

Keywords: **WiMAX (Worldwide Interoperability for Microwave Access, WiGrid, point to multi-point (PMP).**

1. Introduction

The main concept of the various smart power grids is tightly coupled to the availability of an underlying communication infrastructure that supports the multitude of monitoring, data collection and control tasks foreseen in future smart grids. The U.S. National Institute of Standards and Technology (NIST) [2] and the IEEE Project 2030 [3] have developed reference architecture models for such smart grid communication networks (SGCNs). The IEEE 2030 reference architecture defines three domains, namely Home Area Networks (HANs) at the customer-side, Field Area Networks (FANs) in the distribution section, which can also include Neighborhood Area Networks (NANs) responsible for collecting the traffic from smart meters, and Wide Area Networks (WANs) in the transmission domain see [4, Ch. 1], [5]. These architectural considerations are technology agnostic, and different wired and wireless technologies including power line communication, WiMAX and Long-Term Evolution (LTE) compete for use in different SGCN domains, see [4, Ch. 5].

The choice of a suitable correspondence innovation relies upon various criteria among which the required system scope and the kinds of information movement with their nature of-benefit (QoS) necessities are among the most essential. These necessities are particular to the brilliant matrix area. For example, HANs cover shorter connections contrasted with FANs and WANs, and planning robotized gadgets at home isn't as basic as the checking, control and security movement that happens in FANs, where inaccurate or deferred data can cause real interruptions. Likewise, ecological attributes, for example, client thickness, which can affect the required system limit, and system availability, thinking about that as some advances may be inaccessible in specific regions, influence the decision of innovation. WiMAX is a fourth era broadband remote innovation and in view of the IEEE 802.16 arrangement of measures. Its highlights are steady with the correspondence and QoS necessities happening in FAN and WAN usage. Specifically, WiMAX offers long-run scope, high information rate, and meets the differing administration prerequisites from brilliant framework applications through its accessible arrangement of administration writes.

The reasonability of WiMAX innovation for NANs and FANs has been researched in the writing, a few field trials [6], [7], and late reviews [8], [9]. Under the umbrella of the NIST Priority Action Plan (PAP) 2 rule [10], territory and limit investigations have been directed for various use models to give a few bits of knowledge of the capacity of WiMAX innovation for backhauling shrewd metering movement. References [11] and [12] consider a heterogeneous Wireless Local Area Network (WLAN)- WiMAX innovation for gathering and backhauling savvy metering movement. This considers expanding the system scope and enhancing the connection quality. Aguirre et al. [13] define the limit gave by WiMAX so as to appraise the quantity of brilliant meters that can be served utilizing this innovation. References [1] and [14] research the execution of WiMAX innovation considering diverse arrangements of FAN applications and system structures.

The previously mentioned works and others, for example, [15]– [17] for the most part affirm that WiMAX is a feasible decision for FAN and NAN applications. Besides, it is inferred that when remote advancements are intended for savvy lattice usage, they ought to be arranged uniquely in contrast to when utilized for versatile broadband (MBB) applications for which they were initially composed. For instance, MBB applications are downlink (DL) driven, while uplink (UL) movement overwhelms in numerous shrewd framework applications. Robotized gadgets in keen networks produce moderately little per-gadget movement, which brings about expansive total information rates however. Moreover, the scope arrangement is required, while it is just very alluring in cell systems [18]. Appropriate exchanges in the writing incorporate [12], [16], and [19], which propose a sort of-administration to activity mapping for shrewd metering through WiMAX, and streamlines the base station (BS) transmission control, individually.

In light of this, the WiMAX Forum has characterized another framework profile in light of the IEEE 802.16 arrangement of norms considering keen matrix prerequisites [20]. This alleged WiGrid profile is produced in a two-stage approach known as WiGrid-1 and WiGrid-2. In the primary stage, the benefits of the present highlights that as of now exist in the IEEE 802.16e and IEEE 802.16m guidelines are considered. The average arrangement of these highlights is altered considering shrewd framework organize qualities and necessities.

In the second stage, the benefits of the current revisions created in the IEEE 802.16p and IEEE 802.16n benchmarks, separately, intended for empowering machine-to machine (M2M) correspondence and expanding the system unwavering quality for WiMAX systems, are considered. A diagram of these two standard changes has been exhibited in [21], where shrewd matrix is perceived as one of the utilization cases which require both more prominent system unwavering quality and M2M correspondence. In the second stage, these two guidelines will additionally be altered with highlights particularly intended for SGCNs. Up until now, the WiMAX Forum has for the most part centered around the principal period of the WiGrid advancement and recommended a few changes to the current WiMAX design. These alterations are abridged in the "WiMAX Forum System Profile Requirements for Smart Grid Applications" [18]. They incorporate a dynamic Time Division Duplexing (TDD) UL/DL proportion from 1 to 1.75 and the help of 64QAM transmission.

II. Related Work

Heterogeneous WiMAX for AMI communications [1]: Here, network has heterogeneous Wireless Local Area Network (WLAN)-WiMAX technology for collecting and backhauling smart metering traffic. This allows for extending the network coverage and improving the link quality

Performance analysis of WiMAX [2-3]: These paper study on selection of Field Are Network (FAN) and Neighborhood Area Network (NAN) dynamically. Also capable of configuring upload and downlink bandwidth in the network..

3. PROPOSED WORK

In this paper, Priority based solution approach with Uniformly WiGrid Configurations in Smart Grid Communications, this paper also focus on the first phase of the WiGrid development and optimizes the configuration and/or implementation method for several other existing WiMAX features namely, frame duration, type-of-service to traffic mapping, and scheduling solution. This optimization is conducted such that the key QoS requirements namely, latency and reliability,1 for SGCNs are best met. In particular, our main contributions are summarized as follows.

3.1 Network Creation:

Nodes are important components in WSN which are capable of transmission of packets within the network. Every node has its own set of associated properties which help in many aspects. It is a composition of software and hardware models within it. Hardware components describe various parameters description and values for each. Also, type of material used and its capability to handle different application sets. Whereas software model covers the type of transmission mechanism how the packets should be routed to different nodes within the network. Every node upon receiving data must undergo various layers defined in TCP/IP model and take appropriate action defined at each layer.

Similarly, PWSG protocol is defined at network layer of TCP/IP model. Network creation will consider following assumptions

- All nodes will have same properties
- Deployment of every node is independent of other
- Every node behaves its properties until its energy reaches to threshold value
- Environment is chosen to be free space and its same within the entire region

With all the above assumptions, nodes are deployed with uniform distribution. Selection of uniform distribution is to cover entire region without making any dark regions in the network. Also, connectivity of the network will be maximum with uniform distribution. Free space is chosen since the simulation considers no obstacles within the network. Omni antenna is chosen for transmission and reception packets at each node.

Protocol is defined to generic where total number of nodes and source nodes are being fed as input before start of simulation. There are three types of source nodes. Hence, number of nodes for each type of source nodes is fed as input separately. With this information, random selection is done for every type of source nodes. Colors are given to each type of nodes to distinguish each of them.

3.2 Source Data Generation

All three types of nodes defined are: CBR nodes, VBR nodes and NRT nodes. Each of these nodes will have a timer associated with it. Properties of each type of nodes is described below:

- CBR nodes will generate data with constant rate. Period of data generation is set at the beginning.
- VBR nodes will generate data with varying rate. Data rate selection is dynamic and random. Randomness is to bring real time scenario.
- NRT nodes will generate data randomly. There is no periodicity of data generation.

Any node can have only one type of data source added to it. Data generation can be operated by calling start and stop functions.

3.3 Priority Based Routing:

Core functionality of PWSG is defined here. Smart grid environment is set up before simulation begins in the network. Requirement of smart grid is to achieve handling of several types of services at with collision avoidance and fulfilling real time demand. Priority levels of packets are defined here.

- CBR Packets: Highest priority packets
- VBR Packets: Second priority packets
- NRT Packets: Least priority packets

Every node will walk through their modules when a packet is received. Protocol will just queue the lower priority packets. Handler mechanism is defined with timers associated with them which will handle those packets when the node is free. Highest priority packets will be forwarded without any delay.

3.4 **Integration:**

All the modules PWSG Agent, Routing module, Timer and Queue are integrated together which correspond the actual behaviour of the protocol. Node numbers, selection of source and sink nodes, timers are all dynamic in nature and protocol can adopt of any of changes without any issues. Thus, protocol behaves as generic rule to all types of network inputs.

Pseudo code of the algorithm for various modules are defined below:

Segment 1: Header file of PWSG Agent

```
void sendPWSGHello(void);
void sendBCbyME(void);
void sendMEdata(nsaddr_t);
void sendCHmessage(void);
void recvPWSG(Packet *p);
void recvHello(Packet *p);
void process_VBR_pkts();
void process_NRT_pkts();
```

Segment 2: Various events handling

```
evt = new PWSGEvent(1, 1.0);
htimer.handle(evt);
evt = new PWSGEvent(2, 5.0);
htimer.handle(evt);
// VBR Timer
evt = new PWSGEvent(3, 0.05);
htimer.handle(evt);
// NRT Timer
evt = new PWSGEvent(4, 0.05);
htimer.handle(evt);
```

Segment 3: Process NRT packets

```
void PWSGAgent::process_NRT_pkts() {
  while((p = nrtQUEUE.deque())) {
  if((CURRENT_TIME-last_CBR_time) > 0.2 && (CURRENT_TIME-last_VBR_time) > 0.2) {
     // process these packets
  } else {
  break;
  }
}
```

Segment 4: Process VBR packets

```
void PWSGAgent::process_VBR_pkts() {
  while((p = nrtQUEUE.deque())) {
  if((CURRENT_TIME - last_CBR_time) > 0.2) {
     // process these packets
```

```
} else {
  break;
  }
}
```

Segment 5: Priority based packets selection

```
if(ch->ptype() == PT_CBR) {
  // process CBR packets
} else if(ch->ptype() == PT_VBR) {
  // process VBR packets
} else if(ch->ptype() == PT_NRT) {
  // process NRT packets
}
```

Segment 6: Queue management

```
class pwsg_rqueue {
  void  enque(Packet *p);
  Packet* deque(void);
  Packet  *head_;
  Packet  *tail_;
}
```

4. System Architecture

Figure 4.1 shows system architecture of smart grid communication network. Smart Grid is a concept regarding digital technology application and electric power network. It offers a lot of valuable technologies that can be used within the near future or are already in use today. Smart Grid includes electric network, digital control appliance, and intelligent monitoring system. All of these can deliver electricity from producers to consumers, control energy flow, reduce the loss of what, and make the performance of the electric network more reliable and controllable.

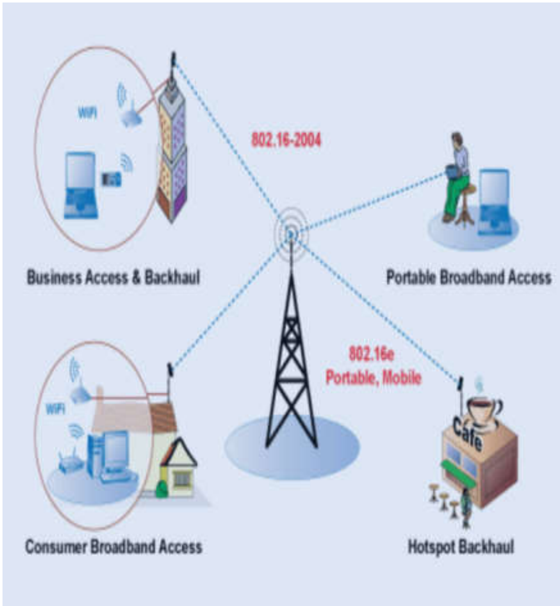

Fig 4.1 System Architecture

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producers to consumers, control energy flow, reduce the loss of what, and make the performance of the electric network more reliable and controllable.

These systems are made possible by two-way digital communications technologies and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers mostly seen in big improvements in energy efficiency and reliability.

Significance of smart grid is that it builds on many of the technologies already used by electric utilities but adds communication and control capabilities that will optimize the operation of the entire electrical grid. Smart Grid is also positioned to take advantage of modern technologies, such as plug-in hybrid electric vehicles, various forms of distributed generation, solar energy, smart metering, lighting management systems, distribution automation, and many more.

Smart grid is a modern technology introduced which can establish communication between various type of networks. Network consists of several types of devices such as static, mobile, relay station, base station. All these types will have their own system configuration. Communication within the network will be via wireless mode. All consumer premise equipment (CPE) will transfer their data to relay station. Relay station in turn transmits the data to base station. Base station will be connected to many relay stations. Therefore, it will high handling capacity and receive data from multiple such resources at same time.

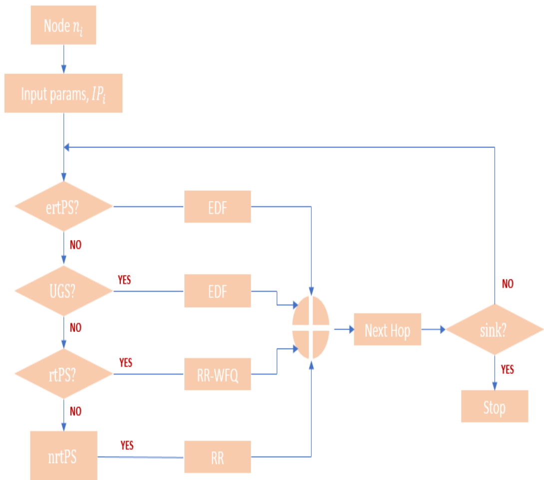

Fig 4.2: Flow Diagram of WiGrid in Smart Grid Communication

Above figure shows the flow diagram of WiGrid. The network is consisting of various types of services and each is meant to satisfy certain quality of services (QoS). All these scheduling types of Smart Grid are defined below: Real Time Polling Service (rtPS): rtPS are the ones which satisfy variable bit rate (VBR) applications. Here, the necessity is to achieve low latency and high reliability.

Enhanced Real Time Polling Service (ertPS) There are applications which very high reliability and much lower latency such as military applications. Such type of applications demands for enhances real time services.

Non-Real Time Polling Service (nrtPS) nrtPS are ideal cases of study and offers unicast requests. Applications such as traffic signals where quality parameters are of not much important to be taken care.

Unsolicited Grant Service (UGS): UGS types are the ones that suitable for serving constant bit rate (CBR) applications. UGS guarantees the bandwidth; it is a suitable choice for traffic that requires low latency and high reliability. Due to this, low latency is sufficient for such type of services.

Source node n_i will be initial node participate in data transmission. The data it will be fetching will demand for any type of services defined above and is supplied as input parameters 〖IP〗_i to node n_i. Once, it takes the inputs, it will decode and understand the type of service, then priority-based selection approach is followed.

Proposed protocol gives higher priority to ertPS services which are most important type of services. If such services enter the node, then currently handling services will be pushed back and this will be taken first. Earliest deadline first (EDF) protocol is defined to make this selection. Similarly, EDF is applied to UGS type of services also. If already handling services is of same type as the newly arrived then, first in first out (FIFO) is followed For rtPS services, Round Robin Weighted Fair Queue (RR-WFQ) approach is applied where these services are maintained in a separate queue weights are assigned to each of these services.

Finally, nrtPS services is least important is handled via Round Robin protocol. Due to its least significance, system will not demand for this type of service to be handled earliest. After selection of service to be served, selection of next hop is done through shortest distance vector protocol where node which is closer to the sink node than the sender node will be chosen as the next hop and data will be transmitted to it. Every hop along the transmission will follow the same protocol and finally the data will be sent to sink node.

5. Performance Analysis

5.1 Average Latency

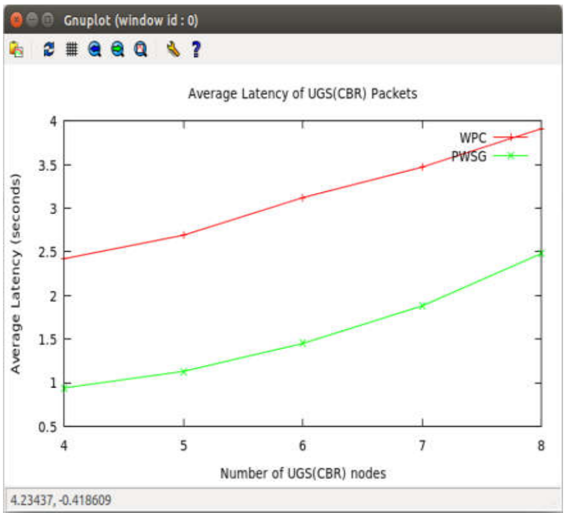

Fig 5.1 Average Latency of CBR Packets

Latency is the amount of time consumed to transmit packet from source to destination. Fig 7.1 shows the result of average latency of CBR packets. CBR are the high priority packets generated by source nodes within the network. Proposed PWSG protocol uses priority-based selection of packets to meet the requirement of smart grid network. There are three types of services are studied. CBR are the high priority packets. Variable Bit Rate (VBR) and NRT (non-real time) are the second and third priority packets respectively. Results are compared with WPC protocol where packets are being transmitted with first-in-first-out (FCFS) basis. This would not fulfil the demands of smart grid. Therefore, PWSG improvises the network life by providing better service.

5.2 Packet Collision Count:

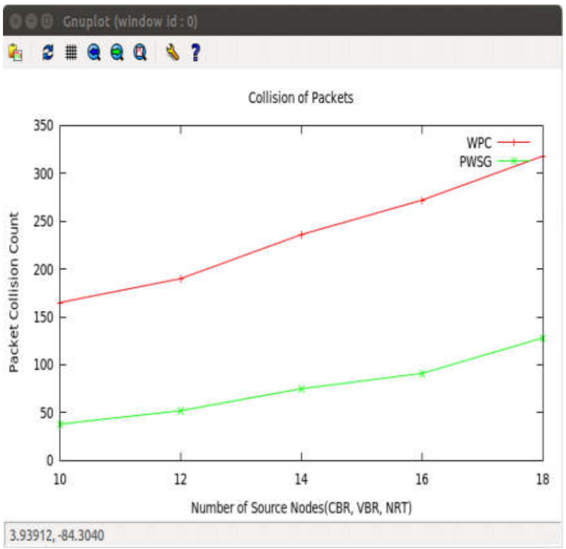

Fig 5.2 Packet Collision Count

Collision of packets is due to several factors such as occupying channel at the same time, receive of packets from multiple sources at same time. Fig 7.2 shows the results of packets collision with different number of source nodes. Since PWSG uses priority-based packet selection with respect to different type of service, a queue management is defined to queue least priority packets to transmit them at later time. Whereas in WPC, because of FCFS packets will be just forwarded as soon they enter a node. This leads to collision of packets in channel and within node as well. Hence, the result shows that the packet loss can be reduced with proposed protocol. Increase of packet collision with higher number of source nodes is due to more number of packets enters the channel. This can be reduced further by allowing packets to generate at different time frames.

5.3 Packet Delivery Ratio

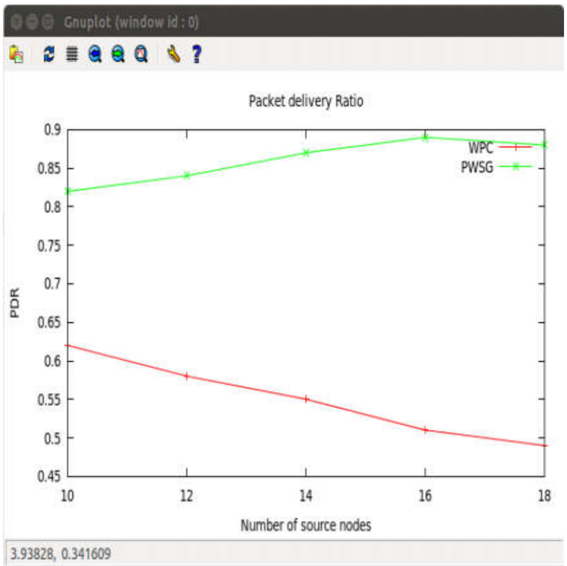

Fig 5.3 Packet Delivery Ratio

Fig 5.3 shows the results of packet delivery ratio of PWSG v/s WPC protocol. Delivery of packets is to ensure that packet will reach to intended recipient. Here, the sink node. As discussed before, because of priority-based selection and queue management system, good packet delivery ratio can be achieved. Therefore, PWSG shows better results for PDR when compared to WPC protocol.

6. Conclusion

In this paper, an efficient Priority based solution approach with Uniformal WiGrid configurations in Smart Grid Communications(PWSG) is studied. Smart grid provides several types of services among which CBR, VBR and NRT are the important ones. These services and their input parameters are studied. Further, all these are services are configured are several nodes which played the role of source nodes generating the data. These types of nodes are differentiated by the amount and rate at which the data gets generated. Protocol introduces the mechanism of priority-based service provisioning by setting different priority levels to these services. Higher priority packets are routed without any delay whereas lower ones have queued them first later handled via FCFS service. This brings quality to the system by introducing better packet handling mechanism and leads higher reliability and throughput.

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