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# Pilot Protection Schemes over a Multi-service WiMAX Network in the Smart Grid

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*Abstract*—**Pilot protection schemes, extensively used in high voltage transmission grids, are one of the most effective methods of protecting networked distribution lines that use high speed inter-relay communications for fast fault detection and isolation. This paper examines the use of an IEEE 802.16/WiMAX based wide area smart grid communications network to support such schemes in the smart grid. The IEC 61850-90-5 based routed GOOSE (R-GOOSE) protocol was considered for the high-speed, peer-to-peer communication among the relays. The paper particularly investigates the radio resource scheduling issues for such event-driven, machine-to-machine (M2M) communication traffic over a multi-service WiMAX network. A new QoS scheduling service called 'Expedited Effort (EE)' is proposed that uses a fast bandwidth request and a prioritized grant mechanism to transfer the time-critical pilot signals. Simulations were conducted using an OPNET simulation model to analyze the performance of the pilot protection traffic under both the conventional Best Effort (BE) and the proposed EE services. The initial results indicate that the proposed EE service is able to transfer the pilot signals within a guaranteed delay bound as opposed to the conventional BE service.**

***Keywords—WiMAX; Pilot Protection; M2M Communication Smart Grid; IEC 61850***

## I. INTRODUCTION

One of the key objectives of the next generation smart grid is to provide reliable energy delivery to its customers by using advanced protection and control mechanisms in the distribution grid. The future electrical grid needs to support a large number of renewable energy generators that requires a fully meshed distribution grid to cope with the resulting time-varying bidirectional power flow. One very reliable method of protecting such networked feeders is to use pilot protection schemes which are extensively used in the high voltage transmission grids [1].

Pilot protection schemes, such as directional comparison blocking (DCB) and permissive over-reaching transfer trip (POTT) use high-speed, peer-to-peer communications among the relays for fast fault detection, isolation and restoration (FDIR) activities. Such schemes require a communications channel that can transmit a binary, on/off, permissive or blocking signal reliably within a strict delay bound (See Fig. 1). Hence, one of the key challenges of deploying widespread pilot protection schemes in the distribution grid is to ensure a communication media which is fast, reliable and able to provide guaranteed performance [1]. The traditional solutions include sending an analog tone over a copper line, power line carrier system, microwave, or fiber-optic cable [2]. However, most of these solutions are proprietary and use dedicated links between two substations that often comes with high capital and operating expenses.

In recent years, intra-substation communication has been standardized through the IEC 61850 based GOOSE (Generic Object Oriented Substation Event) profile that can operate over the commercially available Ethernet based networks. More recently, IP (Internet Protocol) routing functionality has been incorporated in the GOOSE profile based on the IEC 61850-90-5 standard to facilitate information change between different IP subnetworks using both unicast and multicast techniques [3]. This important advancement in the inter-substation communication paves the way to use an IP based integrated smart grid communications network for advanced protection and control functions in distribution networks.

While conventional telecommunication networks are optimized to support various multimedia applications such as Voice over IP (VoIP), streaming media, and web browsing, the traffic requirements for M2M applications such as pilot protection schemes are quite different. In case of multimedia applications, while it is important to ensure proper QoS, an even more vital issue is the Quality of Experience (QoE) i.e. how the end-user perceives and experiences the services. On the other hand, most machine-to-machine (M2M) applications require reliable delivery of a single message within a strict delay bound as they act as the triggering points for the underlying protection and control systems. Many of these time critical messages contain a Time-To-Live (TTL) field which implies that the message will lose its relevance if not delivered within the specified time. Hence, their performance has to be measured in objective terms (e.g., message delivery success rate) against a set of pre-defined QoS attributes such as delay and packet-loss. For such applications, the key challenge for the wireless communication network is to efficiently allocate radio resources among different classes of traffic so that their end-to-end QoS requirements are met.

In this paper we examine the use of an IEEE 802.16/WiMAX based wide area wireless network to support pilot protection schemes in the smart distribution grid. The IEC 61850-90-5 based routed GOOSE (R-GOOSE) protocol is considered for high-speed, peer-to-peer communication among the relays. In particular, we investigate the radio resource scheduling issues for transferring the event-driven pilot signals amidst other smart grid M2M traffics such as

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meter reads, sensor reports and demand management applications. Using discrete event simulations based on OPNET, we first investigate the performance of the pilot protection traffic under the existing WiMAX scheduling scheme. We then propose a new QoS scheduling service called ‘Expedited Effort (EE) that uses a fast bandwidth request and a prioritized grant mechanism to serve the time-critical pilot signals within a guaranteed delay bound.

The rest of the paper is organized as follows. Section II describes the protection application model considered for this study and specifies the key traffic requirements. Section III discusses the possible use of the IEEE 802.16/WiMAX standard for supporting pilot protection applications and highlights the key challenges in terms of radio resource scheduling for the pilot protection traffic. Section IV presents the simulation environment and scenarios, and describes the key assumptions made for the study. Section V analyzes the performance of the pilot protection traffic over the conventional scheduling service. Section VI introduces the proposed QoS scheduling service and describes its key tenets and analyzes its performance under the pilot protection traffic. Finally, section VII concludes the paper.

## II. APPLICATION MODEL AND TRAFFIC REQUIREMENTS

Under a pilot protection scheme, each pilot relay measures voltage and current at its own terminals to calculate the impedance to a forward or reverse fault. This information is then exchanged between the peer relays in the form of a blocking signal if the fault is behind the relay (for the DCB scheme) or a permissive trip signal if the fault is in front of the relay (for the POTT scheme) as illustrated in Fig.1. A pilot trip occurs only if a relay detects a fault and a permissive trip signal is received (or a block signal has not been received) from the remote end. For more details about the pilot protection scheme, please refer to [4].

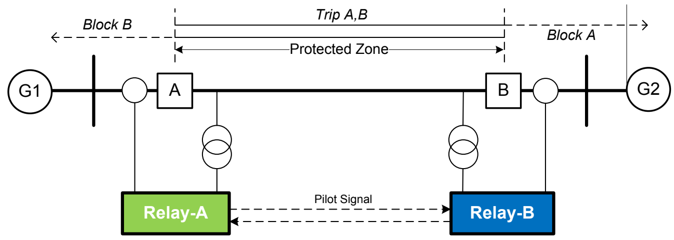

Fig. 1 Pilot Protection scheme in a two terminal feeder using POTT and/or DCB scheme

When a fault occurs, each relay sends a pilot (trip or block) signal to its remote counterpart based on the type of the protection scheme used. For example, if the POTT scheme is used and the fault is located between terminal A and B, a trip signal is exchanged between terminal A and B that allows permissive tripping in both of the relays. On the other hand, if the DCB scheme is used and the fault is outside the protected zone, for instance to the left of terminal A, A sends a block signal which prevents tripping in B. A special case is the combined use of POTT and DCB scheme for better dependability [1]. In such case, each relay communicates with two peer relays and therefore generates two (one trip and one block) pilot signals. In addition, a pilot protection scheme can also be deployed in a three-terminal line which involves the exchange of pilot signals among three relays. However, to keep the scope of this paper limited, we focus on the two-terminal, standalone protection scheme only.

We assume that the pilot signals are encapsulated in a GOOSE packet and sent over the IP network. The key communication requirement here is to transfer the pilot trip/block signals within a specified time otherwise the breaker will trip automatically. Another important requirement here is that the signal should be sent as fast as possible. This is because the operation of the associated switch/circuit-breaker is often delayed by the data communication time plus some margin [5]. Hence, the lower the communication delay, the faster the protection scheme will operate. According to [1], the total operating time for the POTT scheme is 30-35 ms and for the DCB scheme is 80 ms including the relay operating time (for a 50Hz power system). Considering the operating time of the high-speed digital relays (less than 5ms), a pilot signal has a delay budget in the order of 25-30 ms for the communications network.

## III. PILOT PROTECTION TRAFFIC OVER WIMAX

Although a pilot protection scheme requires peer-to-peer message exchange between two or more relays, in a cellular wireless environment like that of WiMAX, all the data packets have to traverse via the base station (BS). However, here the BS will only act as a transparent relay for the incoming data packets and route them to their intended destinations without any application-layer processing. Thus, each pilot signal message is associated with an uplink (UL) component i.e. from source relay to the BS and a downlink (DL) component i.e. from the BS to the destination relay.

As specified in the IEEE 802.16 standard, the BS scheduler provides radio resource allocation for both the UL and the DL connections [6]. Unlike the DL connections, the bandwidth requirement information is distributed in the subscriber stations (SSs) for the UL connections. Therefore, a request mechanism is required by the SSs to indicate to the BS their bandwidth needs. For UL bandwidth allocation, the BS scheduler separates each connection based on a particular set of QoS attributes (e.g., throughput, latency and jitter) using a unique service flow ID (SFID). To facilitate radio resource sharing among different users, the IEEE 802.16 standard defines five scheduling services or QoS classes [6]. A brief summary of them is listed in Table I.

TABLE I FIVE SCHEDULING SERVICES OF WIMAX

| ***QoS Class*** | ***Traffic Characteristics*** | ***QoS Parameters*** |
|---|---|---|
| Unsolicited Grant Service (UGS) | Periodic, fixed-size data packets (e.g., TDM Voice ) | Max Data Rate, Latency |
| Real-time Polling Service (rtPS) | Real-time, periodic, variable-size data packets (e.g., Streaming Audio/video) | Max Data Rate, Min Data Rate, Latency |
| Extended Real-time Polling Service (ertPS) | Real-time, periodic, variable-size data packets with ON-OFF intervals (e.g., VoIP) | Max Data Rate, Min Data Rate, Latency, Jitter |
| Non Real-time Polling Service (nrtPS) | Delay tolerant applications (e.g., File Transfer) | Max Data Rate, Min Data Rate |
| Best Effort (BE) | Regular data packets (e.g. Web browsing) | Max Data Rate |

Traditionally, these QoS classes have been designed to support various multimedia applications. However, the pilot signals are triggered only after a fault event. Note that the time of fault occurrence in the distribution grid is a random phenomenon caused by various external factors such as storms, bushfires, lightning, trees and animals. A protected line can be without faults for days and even weeks. Hence, persistent scheduling strategies such as UGS, rtPS, ertPS and nrtPS that allocate periodic data grants/polls to the SSs are not suitable since all of the polls/ grants will be wasted during the normal operation of the feeder. This leaves the configuration manager with one scheduling choice – the BE scheme which uses random access based bandwidth request (BW-REQ) mechanism to support bursty data transfer. Fig. 2 depicts the various delay components of the pilot signal transmission under the conventional BE scheduling class.

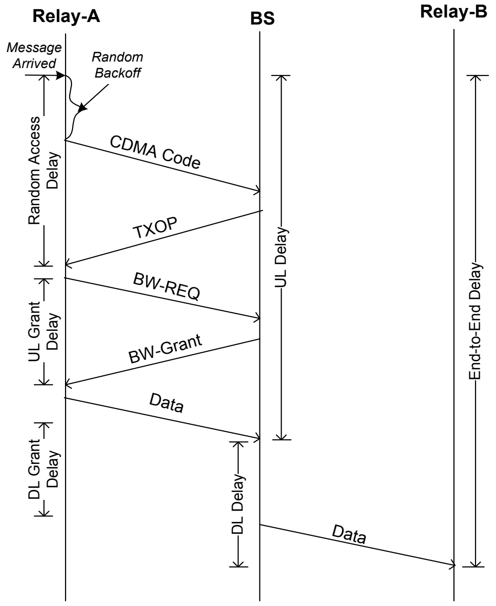

Fig. 2 Pilot signal transmission using the BE scheduling service

Under the BE scheduling, whenever a SS intends to transmit a packet, it waits for a random number of frames uniformly chosen from an interval of [0, $W_{min}$-1], where $W_{min}$ denotes the initial backoff window and then transmits a CDMA (Code Division Multiple Access) BW-REQ code using the ranging channel. Contention occurs when two or more SSs select the same ranging code in the same ranging channel. To resolve contention, WiMAX uses the truncated binary exponential backoff (TBEB) algorithm. After each transmission, the SS considers the code lost if no data grant has been received within the subsequent frames specified by the *Contention-Based Reservation Timeout parameter* ($T_c$). In that case, the SS increases its current backoff window by a factor of two until it reaches the maximum backoff window ($W_{max}$). The retry process continues until the maximum number of retries ($m$) has been reached [6].

According to the performance analysis of TBEB algorithm in [7], if $P_t$, and $P_c$ represent the probability that a node will transmit and a collision will occur in an arbitrary slot respectively, then $P_t$, and $P_c$ can be obtained as follows:

$$P_t = 2\frac{\sum_{i=0}^{m} P_c^i + 1}{W_{min}\sum_{i=0}^{m}(2P_c)^i} \tag{1}$$

$$P_c = 1 - (1 - P_t)^{N-1} \tag{2}$$

Where, $i$=0,1,2…,$m$ and $N$ is the number of contending devices in the system. From Eq. (1) and (2), we see that the larger the number of devices in the system, the higher the probability that a code will collide with others.

Now, if the current backoff window of a SS after $j$ collisions is $W_j = 2^j W_{min}\ (j \leq m)$, the average number of frames it has to wait within a backoff retry process is given by:

$$\bar{d} = \frac{1}{2^j W_{min}} \sum_{k=1}^{k=2^j W_{min}} k + T_c = \frac{1+2^j W_{min}}{2} + j * T_c \tag{3}$$

Eq. (3) shows that the average random access delay, $\bar{d}$ increases exponentially with the increase in the number of backoff retries, $i$.

Once the code is received successfully, the BS provides the SS with a small bandwidth grant or transmission opportunity (TXOP) to send the actual BW-REQ message. Once the actual BW-REQ has been received by the BS, it allocates another bandwidth grant to the SS to send the packet. The bandwidth grant delay depends on the on the priority of the scheduling class as well as the type of scheduling algorithm used. Since the BE service is typically used to serve delay tolerant applications (as seen from Table I), it is given the least priority in the scheduler and normally uses a simple round-robin (RR) algorithm for bandwidth grant scheduling. The performance of the RR scheduler can be easily analyzed using an M/D/1 queuing model i.e. exponential distributed arrival rate (λ), deterministic service rate (μ) i.e. one WiMAX frame and a single server queue. According to queuing theory, the average time spent by a packet in an M/D/1 queue is given by:

$$E(W) = \frac{2-\rho}{2\mu(1-\rho)} \tag{4}$$

Where, $\rho$ is the traffic load of the system (=λ/μ). From Eq. (4) we see that the grant delay increases with the increase in the traffic load.

As seen from Fig. 2, the end-to-end (E2E) delay for the pilot signal messages is given by:

$$d_{e2e} = d_{UL} + d_{DL} \tag{5}$$

The overall UL delay is comprised of the random access delay ($d_{RA}$) i.e. the time required to request bandwidth through the CDMA contention process, the grant delay ($d_{Grant}$) i.e. the time required to send the actual BW-REQ and receive a bandwidth grant, the data transmission time ($d_{Tx}$) i.e. the time required to send the actual data packet and other processing ($d_{Proc}$) times in the SS and BS as given by:

$$d_{UL} = d_{RA} + d_{Grant} + d_{Tx} + d_{Proc} \tag{6}$$

On the other hand, the overall DL delay is only comprised of data grant, transmission and processing times as given by:

$$d_{DL} = d_{Grant} + d_{Tx} + d_{Proc} \tag{7}$$

Since the BS knows the exact bandwidth requirements of the DL data packets, no random access mechanism is required. Hence, the overall delay remains almost the same in the DL. Thus, the overall delay under the BE scheduling class is mainly determined by the random access delay and grant the scheduling delay in the UL.

## IV. SIMULATION ENVIRONMENT

To evaluate the performance of the pilot protection application over a WiMAX network, we develop a single cell simulation model using the OPNET modeler 16.0 [8]. Since we are mainly interested in the radio resource scheduling aspects of the WiMAX network, the free space path-loss model is assumed for the study. The rest of the simulation parameters are specified in Table II.

We assume that there are 4 pilot protection relays per km$^2$ yielding roughly 320 relays within the WiMAX cell. Each relay is assumed to communicate with its peer relay only (i.e. 2 relays per protected zone). Each protected zone is assumed to experience a single fault during the simulation run-time of 1 hour i.e. 640 pilot signals during the period of observation. The fault generation times are assumed to be mutually exclusive i.e. each fault is generated at a distinct time. This assumption is valid since the protection relays are normally time-graded so that the relay closer to the fault is isolated first to minimize its effect on the rest of the system [9]. However, the probability of two faults occurring simultaneously is still there which we will consider at a later stage.

To imitate a multi-service environment, we simulate a variable background BE traffic varied between 100 to 400 pps (packets/sec) with a step of 100 pps. The traffic represents various delay tolerant, bursty M2M applications in the smart grid such as smart metering, demand response, and periodic sensor reports. For application level performance analysis, we use two performance indicators – *Message Transmission Time (MTT)* and *Message Delivery Success Rate (MDSR)*. The MTT represents the end-to-end delay for the pilot signal messages comprised of the delay components given by Eq. (5)-(7). The MDSR represents the percentage of total pilot signal messages that were received before their expiry time.

TABLE II SIMULATION PARAMETERS

| **Parameters** | **Values** |
|---|---|
| Physical Layer | OFDMA, TDD |
| Operating Frequency | 2.3 GHz |
| System Bandwidth | 5 MHz (FFT 512) |
| Modulation & Coding | QPSK, ½ Rate CTC |
| Coverage Area | 5 Km radius (78.5 km$^2$) |
| Frame Duration | 5 ms |
| UL/DL Subframe Ratio | 1:1 |
| MAC Date Rate (Including PHY overheads) | UL : 1.22 Mbps<br>DL : 1.58 Mbps |
| Backoff Windows | 4 – 32,768 |
| Contention Timeout ($T_c$) | 40 ms (8 frames) |
| Maximum Retry Limit ($m$) | 16 |
| No. of Ranging Channel | 1 |
| No. of BW-REQ Codes | 8 |
| GOOSE Packet Size | 128 bytes |
| Background Traffic | 100-400 pps (Exp.) |
| Scheduling Algorithm | Round-Robin (RR) |

For this study, we set the message expiry time to be 30 ms as per our discussions in section II. All the relays are assumed to be in radio resource connected mode during the course of the simulation. This can be achieved by regularly exchanging either periodic ranging messages or explicit status update messages at predefined intervals. However, the exact mechanism is out of the scope of this paper.

## V. THE CONVENTIONAL SCHEME

We first look into the performance of the pilot protection traffic under the conventional BE service. The corresponding MTT and MDSR are shown in Figures 3 and 4 respectively.

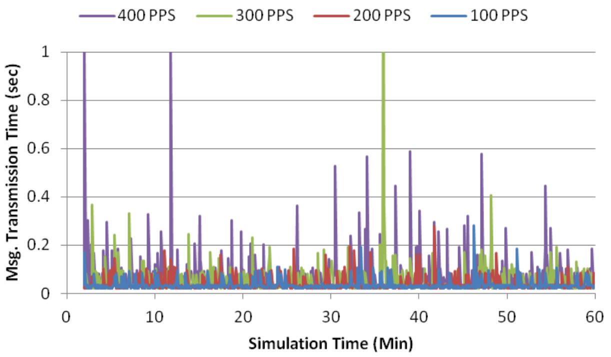

Fig. 3 Message Transmission Time (MTT) under the conventional BE scheduling service

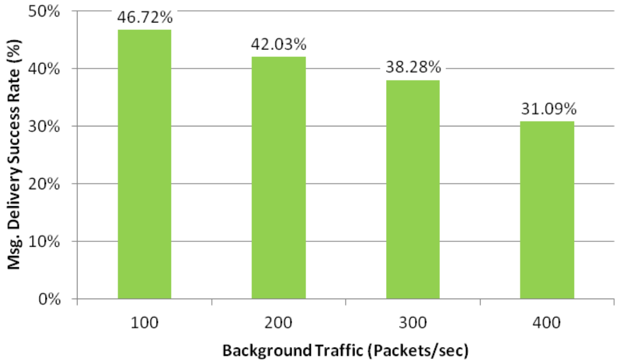

Fig. 4 Message Delivery Success Rate (MDSR) under the conventional BE scheduling service (For TTL = 30ms)

From the results, we see that as the amount of background traffic load increases, the MTT increases which in turn decrease the MDSR since more messages are discarded due to the expired TTL values. To further explain these phenomena, we list the UL and DL delay statistics of the pilot signal messages in Table III. In addition, the UL random access delay and the grant delay is plotted in Figures 5 and 6.

TABLE III UL/DL DELAY UNDER THE BE SCHEDULING SERVICE

| **Traffic Load (pps)** | **Downlink (in ms)** | | **Uplink (in ms)** | |
|---|---|---|---|---|
| | ***Mean*** | ***Std. Dev.*** | ***Mean*** | ***Std. Dev.*** |
| 100 | 6.17 | 0.18 | 28.95 | 22.82 |
| 200 | 6.40 | 0.19 | 32.85 | 28.72 |
| 300 | 6.48 | 0.37 | 45.46 | 74.19 |
| 400 | 6.57 | 0.49 | 61.27 | 91.70 |

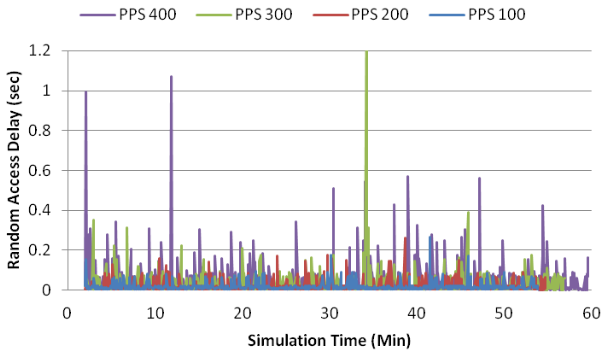

Fig. 5 Uplink Random Access Delay for the pilot signal messages under the conventional BE scheduling service

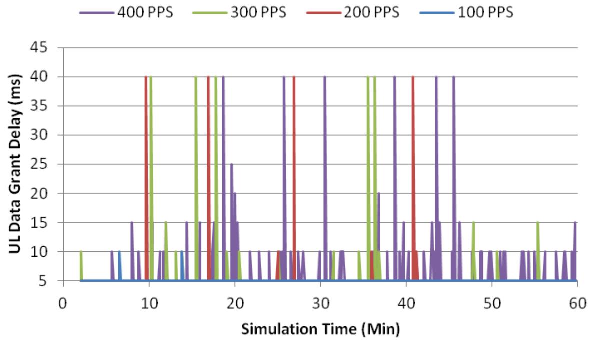

Fig. 6 Uplink Grant Delay for the pilot signal messages under the conventional BE scheduling service

From the results, we see that while the mean DL delay remains almost unchanged, the mean UL delay increases significantly with the traffic load. Also, all the UL delay components are associated with high standard deviation values which indicate large variations from the mean values. Therefore, a large number of pilot signal messages fail to reach destination within the stipulated 30 ms deadline. This is because as the traffic load increases, the probability of collisions increases as per Eq. (1) and (2). With more collisions in the channel, the packets have to undergo more backoff stages. Since each backoff stage is associated with a fixed time-out delay ($T_c$) along with the time spent in random backoff slots as given by Eq. (3), the overall random access delay increases significantly as shown in Fig. 5. Note that the distribution of the random access delay almost mimics the end-to-end delay distribution of the pilot signal messages as shown in Fig. 3. This yields that the overall MTT is highly influenced by the associated random access delay.

Moreover, the UL data grant delays also increase with the traffic load as shown in Fig. 6. This is because since the BS scheduler use the RR algorithm for the BE service to allocate grants, the grant scheduling delay increases with the increase in traffic intensity as per Eq. (4). As the pilot signals packets have the same priority as the other BE packets, they experience the same average waiting time in the data queue. Note that increased grant delay also increases the random access delay. This is because if a device does not receive a grant within the timeout parameter ($Tc$), it resumes the backoff process. This is seen in Fig. 6 where some of the grant delays reach 40ms and therefore, experience additional backoff delays.

## VI. THE PROPOSED SCHEME

From the results in the previous section, it's quite clear that the conventional BE scheduling service of WiMAX fails to meet the required MDSR for the pilot protection traffic. To address this issue, we propose a new QoS scheduling service called 'Expedited Effort (EE)' to transfer the time-critical pilot signal messages. The proposed EE service employs a fast BW-REQ mechanism where the BS reserves two BW-REQ ranging codes (out of 8 for this study) and thus provides a virtual ranging channel (VRC) within the primary ranging channel to exclusively serve the pilot protection traffic. Although the formation of the VRC reduces the number of contention opportunities for the primary channel, the effect is not expected to be severe since it mostly serves delay tolerant applications such as metering readings and sensor reports.

Since within a protected zone, relays at both terminals are expected to pick up the fault simultaneously, we allocate dedicated ranging codes for each of them. Thus, the relays are able to request bandwidth simultaneously without contending with each other. Also, the initial backoff window is set to 0 so that the relays can send the BW-REQ without any random waiting time. The dedicated ranging codes and backoff parameters can be supplied during the connection establishment phase using a time-length-value (TLV) field in the DSA-REQ (Dynamic Service Addition Request) message [6]. The MDSR of the pilot signal messages with the regular and the proposed BW-REQ mechanisms under the conventional BE service is plotted in Fig. 7.

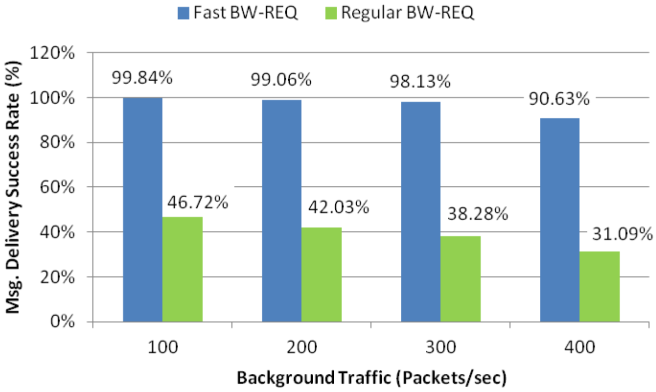

Fig. 7 Message Delivery Success Rate under the conventional BE service with the regular and the proposed fast BW-REQ mechanisms

From the results, we see that the proposed fast BW-REQ procedure significantly improves the MDSR for the pilot protection traffic even under the conventional BE service. However, still a few messages miss the deadline, especially at high background traffic loads. This is because after a successful request, a packet has to compete with requests from its own class as well as other classes to get a data grant from the BS scheduler. Moreover, the increased grant delay could trigger a new backoff retry which would further increase the overall delay. Therefore, to further improve the performance of our proposed EE scheme, we prioritize the pilot protection traffic among all other classes in the BS scheduler using the priority queuing (PQ) technique. The corresponding mean MTT for the BE service, the BE service with fast BW-REQ procedure and the proposed EE service is shown in Fig. 8.

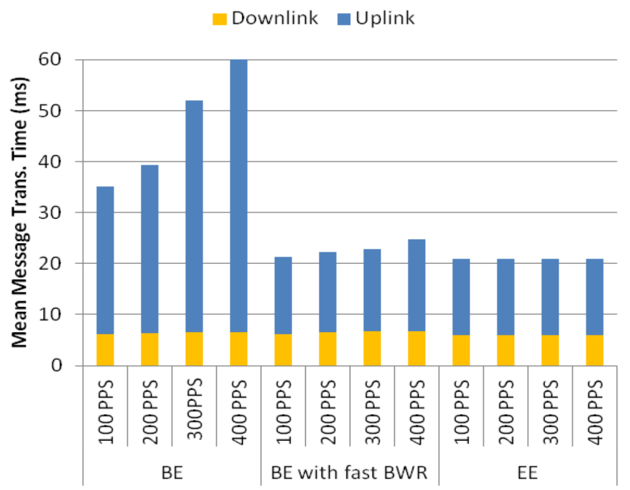

Fig. 8 Message Transmission Time under the BE service, BE service with fast BW-REQ procedure and the proposed EE service

From the results, we see that the proposed EE service is able to provide fixed delays irrespective of the background traffic loads as opposed to the other services. This is because the EE service provides the pilot signal messages with a contention free random access and a guaranteed bandwidth grant in the next frame which eliminates the stochastic variation in the uplink packet delay.

Lastly, we consider the extreme case where two adjacent protected zones experience the fault simultaneously. To address this problem, we propose the following BW-REQ code reuse scheme that prevents multiple relays under the same protection zone to send codes simultaneously (and in avertedly face immediate collision).

**Scheme 1** BW-REQ Code Reuse

1: Assign a sequential Group ID for each pilot protection zone based on their spatial distribution.

2: Assign a dedicated ranging code for each zone.

3: Assign a sequential Member ID, i for each relay under a given zone such that i ∈ $\{1,2,\ldots,M_N\}$ where M is the number of nodes in the group N.

4: Assign a sequential backoff parameter (SBP), j for each member node such that j ∈ $\{0, 1, 2 \ldots (i-1)\}$.

To achieve this, the relays are provided with a sequential backoff parameter (SBP) such that the maximum number of frames a relay needs to wait is '*M-1*' where *M* is the number of relays in the group. However, since most of the protected zones are comprised of 2-3 relays, the additional delay due to sequential code transmission should be limited to 5-10 ms (considering a 5ms WiMAX frame). The value of SBP may depend on the spatial distribution of the relays or it can be a simple random number. However, the group ID must be set sequentially i.e. adjacent zones should be assigned odd and even group IDs respectively. Note that multi-terminal protection zones can also re-use the same ranging code by performing sequential backoff. An illustrative result based on this scheme is shown in Fig. 10. From the results, we see that the second relay of each protected zone is experiencing an additional uplink delay of 5ms (one WiMAX frame) due to the sequential backoff.

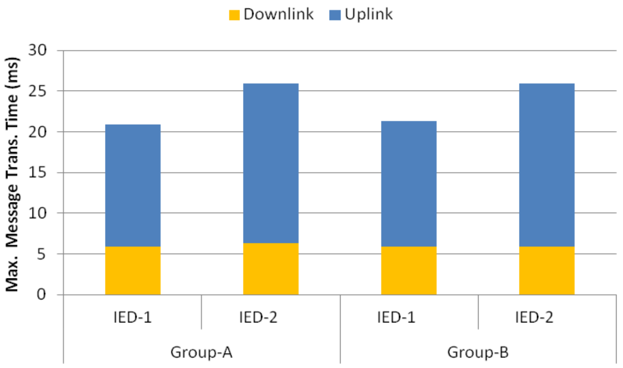

Fig. 9 Maximum Message Transmission Time under the proposed EE scheduling service with the BW-REQ Code Reuse scheme

## VII. CONCLUSION

In this paper, we proposed a new QoS scheduling service to meet the QoS requirements of pilot protection traffic over a WiMAX network. Most of the key concepts of the proposed scheme can also be applied to support other delay-sensitive, bursty M2M applications in the smart grid. To keep the scope of this paper limited, we have not considered the effect of packet loss in the system. However, in practice packet loss may also affect the MDSR of the proposed EE service since it is difficult to incorporate a retransmission scheme in such a tight delay budget. Note that the MTT for the pilot signal messages can be further reduced by using smaller WiMAX frames at a cost of higher signaling overheads.

The continuation of this work includes extending the study to other pilot protection scenarios such as to a combined use of the POTT and DCB schemes, and to multi-terminal protected lines based on multicast communication. In addition, the use of the proposed EE service to other smart grid M2M applications is also worth further investigation.

## ACKNOWLEDGEMENT

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