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Classification of Smart Home Applications' Requirements for the MAC Layer

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Abstract*—Smart homes and Wireless Home Automation Networks (WHAN) face several challenges in terms of cost, scalability, reliability, delay, energy consumption and many others. Smart homes typically have huge number of communicating devices. Efficient management of network resources is a major challenge in such environments. This paper provides insights on how to improve the MAC layer in smart home networks to fulfil the requirements of the different smart home applications. It provides a classification of the different smart home applications and identifies the main requirements and challenges regarding the MAC layer in this environment. It also provides insights for MAC protocols designers by highlighting the main issues in designing MAC schemes for smart home environment. Based on the analysis, the paper highlights adaptability as the most critical and challenging feature for smart home MAC protocols.*

Keywords—smart home; MAC protocol; applications requirements; adaptive MAC

1. INTRODUCTION

The Internet of Things (IoT) is the next evolution of the Internet where devices of all types and capabilities are connected through Internet Protocol and Web Services to provide communication anywhere, anytime with anyone and anything [1]. This concept allows new applications to appear like: smart homes, smart cities, smart grids and others. Smart home concept is envisioned to impact the society and provide several services to the users such as controlling energy consumption, health/children/elder monitoring, security and safety. A smart home can be defined as " a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond" [2]. This definition highlights the important role of smart homes in facilitating people life.

Smart homes and wireless home automation networks (WHAN) are relatively new area of research. There are many challenges in all network layers that need to be solved to achieve the smart home vision. In this paper we focus on the media access control (MAC) layer challenges in smart home environments. MAC layer is responsible for controlling the access to the shared medium among the different devices and applications. The aim of this paper is to identify the main requirements and challenges regarding the MAC layer in the smart home environment.

There are different categories of smart home applications that have different requirements including power efficiency, reliable delivery and QoS, minimizing latency, priority access and many others. Smart home environments typically have large number of communicating devices. Efficient management of network resources is a major challenge in such environments. The MAC layer affects the efficiency and reliability of smart home communications as it is responsible for data exchanging among different devices and different applications. This layer is responsible for fair channel access and power consumption thus affecting the life time of many devices (e.g. sensors). It is also responsible for the latency of data transmission and the prioritization of the different data based on their importance and their QoS requirements. Reliability and efficiency of transmission is a main role for this layer that indicates the successful data transferring between the different entities. Also, error detection and correction is one of the main responsibilities in MAC layer by embedding specific techniques for this task [3]. This layer also affects the hardware and software design of the connected devices thus affects the cost of devices and the cost of smart home deployment [4].

Existing MAC protocols for smart home address some of the smart home applications' requirements like power efficiency and the end to end delay. However, there are still much work needed as reported in a recent survey [4]. Most of the existing solutions are application specific. None of the existing protocol fulfill or tradeoff all the requirements and challenges of the smart home environment.

This paper aims at identifying the main requirements and challenges of the MAC layer in smart home environment. To achieve this aim, the paper provides classification of the different smart home applications' requirements. These requirements are then mapped into MAC layer requirements. This is followed by a comparison of existing MAC protocols based on the identified MAC requirements.

The paper is organized as follows. Classification of smart home applications and their requirements are presented in section 2. Section 3, identifies Mac layer requirements by mapping the applications requirements into the MAC layer. Analysis of existing

MAC schemes based on the identified requirements is described in section 4. Finally conclusion and directions for future work are provided in section 5.

2. SMART HOME APPLICATIONS

WHAN and smart home applications have their own requirements and challenges that should be considered when designing smart home protocols. In this section we classify smart home applications into different categories and extract the traffic characteristics and performance requirements for the different categories. Generally smart home applications can be classified into four main categories: security systems, energy management systems, health and safety systems and residents' convenience applications. After in-depth analysis of the literature we identify the type of messages exchanged and the QoS requirements for each category as follows.

2.1 Security Systems

Several smart home security systems have been proposed in literature. These systems are mainly used for monitoring the house and detecting if there is an unwanted intruder. The work in [5] aims to detect the presence of humans in the house while the main residents are away. The system components are: microcontroller devices for data sending and receiving, sensors and LED data display device. The data transmission and receiving approach is done wirelessly based on ZigBee technology to guarantee fast and accurate data transmission with the use of Xbee Pro devices that can send and receive data in range 1.7 km without barriers. The sensor type used is passive infrared (PIR) to be active only with body heat rather than other objects like rock and others. The system should be water and temperature resistance and robust, LED data displayer used for more clear and bright light over distance Also to prevent hacking the system the programming process must not be secure and no data interruption is allowed.

Another system is proposed in [6]. In this work a prototype is developed for home monitoring and securing using android devices and Arduino Mega ADK (Accessory Development Kit) where various embedded devices and sensors are connected to the ADK and can be monitored and controlled via mobile application. The system uses security cameras and motion detection sensors to monitor the home condition remotely.

After analyzing a number of security systems we can conclude that security systems are mainly transmitting low throughput data in the form of a warning message. This data could be sent periodically (without delay restrictions) or event-based. However, in case of emergency, this data should be transmitted immediately without any delay and with high reliability. Data in this case should have the highest priority. Also when intrusion is detected, some systems send images or video for the house which requires a higher throughput with minimum delay and high priority with some loss tolerance.

2.2 Energy Management and Electrical Control Systems

Energy management is an important area of study for smart home applications. Several systems have been developed to reduce energy waste. As described in [7], there are four categories of applications regarding energy management: HVAC (Heating, Ventilation, Air Condition) with thermostat and motion sensors, lighting applications with temperature sensors, daily devices with thermostat like refrigerator and ovens and lastly digital entertainment devices with motion sensors like TV and video recorder. The authors in [8] present an energy management system that provides a graphical user interface and four main functionalities: home management, real time monitoring and control, energy profiling and energy optimization. Home management function allows the resident to specify the system settings and parameters. It can also detect the presence or absence of the different appliances, show their details to the user and allow him to modify their attributes. The second function is the real time monitoring for the energy status of the selected devices and the activation of the specified control actions (such as security alarm) in case of over-using of energy parameters in any device. The third function is the energy profiling that provides deep analysis for each device energy generation and consumption and presents the whole home energy status to the residents in an understandable and simple way. The fourth function is the energy optimization that uses advanced swarm algorithm to optimize energy consumption in economical way without affecting resident comfort.

Another work proposed in [9] focuses on electrical energy as the main source to operate electrical devices. It aims to prevent energy wastage when leaving electrical appliances operated 24 hours such as lights and others. Hence this study developed a module to allow users remotely control and optimize energy consumption of the electrical appliances such as light, TV, air condition and others. The module approach is based on SMS that sent from user mobile to give orders such as switching on or off that must be executed by a controller device at home. SMS approach is used because of its ability to cover long distance with low cost.

After analyzing a number of energy management researches we can conclude that this type of applications is not time sensitive nor have any restrictions on throughput. However, it requires high reliability and doesn't allow any packet loss. Data can sent periodically, event-based or upon query from the user.

2.3 Monitoring (Health/Elders/children) Systems

A major area of smart home applications is safety and health applications. Several works have been proposed for the safety of children and/or elders and general health monitoring. Monitoring human health by smart home [10] is useful in many aspects such as economy with the ability to detect diseases in early stages will lower overall cost. Another advantage is the ability for elders, people with disabilities and patients to live independently for long time without concerns since medical data is measured continuously and sent to the health care center. Also, the continuous monitoring allows saving life in many emergent situation. The work in [10] develops a system based on sensors connected with patient body that collect information then the information is transmitted to a healthcare center over ZigBee technology. Various demographic parameters can be measured but in this study they use the followings: ECG signal and heart rate, temperature, fall detection and medication reminder. Also, the model allows patients to view their demographic parameters status and report any problem or deterioration in their health conditions.

Another study [11] presents a system architecture of context awareness and situation analysis to provide specific and intelligible services for elder people. The architecture consists of 4 layers: physical layer that contains various kinds of sensors that produce data, context acquisition layer that is responsible of unifying various data formats from the lower layer using XML, situation recognition layer and personalized service layer. Additionally they use several devices to achieve intelligent service: intelligent gateway to control appliances, PDAs to provide portable services and mobile phones for the communications. Moreover, user habits and user preferences are considered to provide more accurate personalized services.

After analyzing several systems to monitor elders, children and/or health we can conclude that most systems are using either scalar sensors to report measurements or video sensors. In the first scenario, the data has low rate and can be sent periodically with moderate delay and high reliability requirements OR event-based in case of emergency and in this case the data has low rate, high reliability and strict delay requirements. In the second scenario, images and videos are transmitted continuously or upon request. In this case some loss packets are permitted while high throughput is required with moderate delay requirements.

2.4 Residents Convenience

The last category of applications aims at increasing comfort for the users and provides some entertainment services. The authors in [12] design and implement a home control and monitoring system as an Android application based on Restful web services. The system consists of three components: remote environment represented by the mobile application, home gateway represented by micro web server running on Arduino with Ethernet technology and home environment that contains the appliances. This architecture is low cost and flexible and can be customized to different applications scenarios so if any new device added to the Arduino this will appear to the user in the mobile application. Moreover, as shown in Figure 1, various controlling functionalities are provided by the mobile application such as remote connection with the Arduino, remote control and monitor of the appliances and manage schedules. Such kind of applications in smart home requires reasonable delay bound and reliability to run efficiently, however, these are non critical applications and can have lower priority.

2.5 Other General Requirements

Beside the application-specific requirements mentioned previously, there are some other requirements that are common for all smart home applications.

Most smart home application use battery operated sensors and mobile devices for the different measurements needed to control the house. Consequently, energy consumption and battery life are major concerns for all applications. Saving energy is a major aim for all applications especially with the fact that network communication is a major source of energy consumption. Any MAC protocol should be designed to save energy as much as possible.

Another requirement is the system scalability. Any smart home system can have large number of nodes (appliances, sensor devices) and this number can increase gradually. Also the system should be flexible to allow new nodes to join or leave when needed.

A third important requirement [13] is resulted from the heterogeneous environment and the integration of more than one application type in a smart home system. Dealing with heterogeneous devices and services, various data formats, dynamic network topology where parts of the system can leave or join suddenly is other important requirement for any smart home design.

A last requirement for all smart home applications is the low cost for installing or running the application in terms of resources needed.

3. SMART HOME MAC REQUIREMENTS

In this section, we interpret the application requirements into MAC layer requirements. First, we summarize the most important issues and constrains affection the MAC design as follows:

- Most smart home applications are based on the use of sensor devices and/or sensor networks to monitor the different environmental conditions; thus energy conserving should be a major aim for the MAC scheme.
- Mobility requirements like the ability to discover or remove new devices and services to/from the application should be satisfied. This also means the MAC scheme should be adaptive to allow new nodes/applications without affecting the performance for the existing ones.
- Both synchronous and asynchronous model of communication should be considered.
- Periodic and non periodic data transmission modes should be considered.
- Event-based and query-based interaction modes should be allowed.
- Performance analysis should be based upon delay, reliability and throughput requirements.
- The MAC scheme should allow different priority levels and also static and dynamic priority assignment for the different applications.
- Low-cost, heterogeneity and scalability are major requirements that should be taken into account.

Also after the analysis done in the previous section in the literature, we found that the most important application requirements mapped to MAC requirements are represented by those parameters:

- Delay requirements (very critical, high, medium, low)
    - MAC protocol should support different priority levels
    - Priority level should be dynamic – static priority is not enough as some priority levels may changed with context
    - Context awareness
    - Fairness to all data types for not starving low priority data
- Throughput requirements (high, medium, low, elastic)
    - Hybrid approach should be used as contention-based can't guarantee a minimum throughput while contention free with fixed time slots is not efficient
- Reliability (zero packet loss, some tolerated loss)
    - Resending of lost packet quickly
    - Reduce collision ratio
- Saving power consumption
    - Suitable sleeping schedule and save power mode should be implemented
    - Reduce collision for not wasting power
- Scalability requirement
    - Use contention-free if ratio of collisions increase
    - Fair access to all applications
- Mobility requirement
    - Context aware
    - Flexible to adapt to dynamic environment

So as a conclusion, MAC protocols design or enhancements for WHAN in the future should not serve specific type of applications but to find the most suitable MAC scheme that is able to fulfill most of these requirements in one design. So , to meet all these requirements MAC scheme should be adaptive, dynamic and context aware. Moreover, from our own perspective we think the

most outstanding requirement that need to be considered in MAC protocol design for WHAN is being adaptable by giving multiple priority for the data type to be transferred in the network.

4. ADAPTIVE HYBRID MAC PROTOCOLS

According to the results we obtained from the previous analysis of smart home applications requirements, we conclude that adaptability in MAC protocol design is a must in order to satisfy and guarantee multiple requirements in one design. So in this section we will review adaptive/hybrid MAC schemes to study and identify techniques used to apply adaptability concept in different perspectives along with requirements considered in these protocols.

- Zebra MAC (Z-MAC) [14]

Z-MAC protocol (Rhee et al., 2008) is combining the benefits of contention based protocols and contention free by combining CSMA with TDMA. The proposed protocol is adapted according to the contention situation in the network. So in high contention case the protocol behave in TDMA approach and that results in reducing collision and enhances the medium utilization; and in low contention case the protocol follows the CSMA approach and that results in reducing the latency and enhancing the medium utilization also. Generally, this protocol improves the performance in power saving in the case of medium to high contention networks.

- Context Aware MAC protocol (CA-MAC) for WBAN [15]

As wireless body area networks (WBAN) is used in many smart home applications for health monitoring, we will consider one of its main promising protocols in more depth. There are several MAC schemes developed for WBAN following the contention free or contention-based approaches, but they lack in the adaptability to various traffic needs [16].

As stated in [15], there is specific problem mostly occurs in WBAN which is the time varying channel that causes deep fading of the transmitted data which means the disability of the receiver to detect and receive the packets since received signal strength is below the receiver sensitivity level. Consequently, packets loss occurs because of the body movement. However, this problem can be handled by incorporating contention based mechanism. Another problem that may occur in WBAN is the change of traffic load according to the surrounded environment and conditions such as the sudden fall of patients.

To solve these problems, in [15] the authors propose context aware MAC protocol for wireless body area networks by providing traffic aware and channel aware mechanisms. The protocol is hybrid of contention based and TDMA approaches. The aim of this protocol is to differentiate the priority of transferred data so the emergent cases or real time data must be transmitted with a high priority, and also to decrease the loss of transmitted packets. The channel awareness solves the fading problem by dynamically adjust the network frame to allow contention communication so the lost packets can be retransmitted timely rather in TDMA mechanism. In other words, if a packet is lost in its specified time slot then retransmission happens using contention-based mechanism. The results show that the proposed protocol reduces the packet loss and hence providing reliable and efficient communication.

The frame structure in the CA-MAC protocol consists of three parts: beacon, contention part, and TDMA part. The beacon part and the whole frame length are fixed but length of the other two parts are changing adaptively based on the network and transmitted data conditions. At first the master node will broadcast beacon packet for communication initialization then each sensor will broadcast beacon packet to identify the frame structure according to the required needs, the contention part at the beginning will set to short length (one slot) since it will not be used unless the channel status worsen and deep fading occurs. If this happened then the contention part will increase based on number of lost packets. However, a tradeoff between data reliability and data collision must be considered so the contention part can't increase freely. As a result the final contention length (FCL) is calculated based on two factors: number of consecutively dropped packets (NCDP) in the channel and time of data collision (TDC) among all sensors. Another function for this proposed MAC protocol is the traffic awareness to give different priorities for the transmitted data. So bandwidth and sampling rate will be assigned to the sensors dynamically according to their traffic needs. Hence scheduled TDMA slots will be allocated to the sensors to transmit continuously periodic data and return to be sleep mode at their inactive period. This will increase channel utilization. If any emergency case is detected by the master node, beacon packet will be sent by master node with more allocation slots for the concerned sensor while other sensors will stop transmission and release available bandwidth to give priority for this emergency case. Moreover, polling based TDMA mechanism applied for time critical applications, so if the sensor node wants to send more packets, the moreData field set to 1 and master node will count this field and allocate the wanted slots to the concerned node.

At the end simulation of the proposed protocol is carried out to measure and compare its performance in terms of packets loss in the entire network. The results are compared to context aware TDMA based MAC protocol described in [16]. The simulation environment is a star topology with one master node, three sensor nodes, and IEEE 802.15.4 as physical layer. Also, deep fading conditions provided at the simulation environment to test the effectiveness of FCL step. The results show that packet loss rate in CA-MAC is between 3.61%-3.99% while in TDMA MAC is around 7.45%. So the CA-MAC protocol decreases number of lost packets

and increases data reliability due to incorporating contention based mechanism with limited bound to save the network from collision.

This protocol is very promising and is considered as a good step for MAC protocol adaptability and we think it can be modified to serve smart home applications especially in similar fields such as health and security monitoring. It allows various data priority levels and provides reliability thus it is suitable for many smart home critical applications.

- Delay Controllable Protocol (DC-Protocol) [17]

DC-Protocol is another protocol developed to cope with smart home applications. Its main motive is to achieve fairness especially for low priority data. According to [17], the data that is transferred within the nodes in most of the WHANs are having different priorities and most of the solutions are giving the high priority data bounded delay under any given data traffic load. That results in infinite delay bounds for low priority data. So the high priority nodes will always access the channel before other data nodes. To solve this problem the authors in [17] propose the DC-protocol that provides fair delay bound for all the data under different classes of priorities. The proposed protocol uses Transmission Ratio Assignable (TRA) algorithm to provide Controllable Mean Packet Delay (CMPD) for all the different priorities data.

DC-protocol is based on CSMA/CD and uses unique mechanisms to provide bounded delay for each type of priority. These mechanisms can be described as: 1) defining three static packet priority low, medium and high and also one bit representing dynamic priority (DPB) to give low data priority the opportunity to content the channel under heavy traffic load; 2) Transmission Ratio Assignable algorithm to assign Successful Transmission Ratio (STR) for each kind of packet priority; and 3) there is five bits called backlog bits that can be used to count transmitted packets within the same priority so this gives fair chance of packets transmission. All these mentioned mechanisms allowed DC-protocol to provide CMPD for all priorities; moreover, there are some factors studied in the simulation model that affect the ratio of CMPD.

The main concept of DC-protocol is achieved by applying TRA algorithm. At smart home networks there are various nodes and each one has its own priority so high priority node generates high priority packets (Rh), medium priority node generates medium priority packets (Rm) and low priority node generates low priority packets (Rl). TRA algorithm is used to allow giving CMPD in case all Rh+Rm+Rl are ready for transmission under heavy traffic load. The analysis of TRA algorithm is that there is STR assigned by TRA for each priority Rh:Rm:Rl respectively and there are two counters for each medium and low priority packets, counter1 increases by 1 whenever higher priority packets transmitted than packets generated by the node, and counter2 that increase by 1 every time packet from the same node priority transmitted. So this algorithm is working like this, if counter1 in medium node equals to Rh then DPB will be set to zero to indicate that the channel is contended to medium priority packets until counter2 equals to Rm which means all medium priority packets transmitted successfully then clear both counter1 and 2. After that when counter1 in low priority node equals to Rh+Rm then DPS will be set to zero to indicate the channel is contented to low priority nodes until counter2 equal to Rl then clear both counter 1 and 2. In this way CMPD can be applicable.

Simulation model is built using C++ programming language and various parameters have been considered. Some of important parameters are: STR value, number of nodes for each priority, mean packet length, MPD for each priority, and many others. The simulation investigates the effect of the mentioned parameters on the MPD. The results show that STR is inversely proportional to MPD, and that means that packet length and number of nodes are approximately proportional to MPD.

In conclusion this protocol provides insights into MAC schemes especially how to achieve adaptability for different data priority while achieving fairness. It is a good candidate to refer to when investigating smart home network parameters.

- User Adaptive MAC [18]

The authors in this study [18] propose user adaptive MAC (UA-MAC) protocol with the aim to reduce the energy consumed while providing end to end data transmission with delay guarantee. To achieve this aim, the protocol adjusts beacon interval according to number of users parameter and also adjusts the size of active window depending on number of users in addition to collision state parameter taking. The proposed protocol is a hybrid approach and combines ALOHA contention based approach with TDMA contention free approach. The authors use hybrid approach to provide tradeoff between power consumption and end to end delay guarantee so if the network situation is in low collision, the protocol is adapted to ALOHA approach to save energy and if the network is in high collision situation, the UA-MAC protocol will change to work in TDMA approach to guarantee the tolerated end to end delay. Again this protocol is complex and resources may be wasted if the network is highly dynamic.

The study describes some of the important WHAN features that should be considered in deriving MAC requirements. These features are low rate, non periodic data, energy critical, short commands and low latency. Also, several MAC requirements are described such as saving energy of the small battery size especially in the wearable appliances, end to end delay especially in control commands to enable smooth interaction between users and appliances. In this study the authors see that the two most important requirements that need to be fulfilled are energy consumption along with end to end delay.

UA-MAC has three main elements. First element is a central coordinator in a star topology with surrounded appliances that is responsible for managing the network topology and for synchronizing various nodes activities by periodic beacon; also managing connections with other appliances and services. This element should be awake all the time. Second element is Wearable Sensor Controller (WSC) which is a sensing device that can be used by users to carry out control command of other appliances at home within any time desired by the user. Third element is electrical appliance node (EA-Node) which is actuator device connected with the home appliances to allow users control them. Both WSC and EA-Node formed in star topology in which WSC represented as master node that can start the operation actively and EA-Node as slave node that will respond passively.

UA-MAC protocol serves specific kind of smart home applications which is controlling appliances based on wearable devices. As an example, this study uses a Magic Ring (MR) wearable device as a WSC to control various appliances like TV, fan, light, radio and others. The number of such controlling devices and applications is increased and thus there is a need for MAC scheme to reduce collision with minimum delay time and power consumption.

The design of the UA-MAC is based upon dividing the superframe between each two adjacent beacons (called beacon interval (BI)) into two portions: active segment (AS) and inactive segment (IS) in which it is optional for low power consumption nodes to enter sleep mode. The AS part is also divided into two parts: one is called contention access period (CAP) for ALOHA transmission and the other is called contention free period (CFP) for TDMA transmission. These parameters BI, CAP and CFP length are assigned adaptively according to the number of users and network collision. In case of increased number of users one or more control command may be sent in the same beacon interval, so the UA-MAC will adaptively reduce beacon interval to reduce the possibility of collision.

There are three different cases may happen in UA-MAC. First, if the control command frame is detected in AS state and there is low collision then the node will receive the ACK within the same beacon interval. Second case, if the control command frame is detected in the IS state and there is low collision then the ACK will be received within the next BI. The last case, if two nodes selected the same time to send frames and no ACK received then they know collision happened so they will send collision flag within the same BI on CFP to ensure no more collision happens, then the coordinator will inform the collided nodes to activate CFP in the next beacon interval; also the related nodes will extend their AS length and transmit in specific time slot in the CFP at the next BI. As we can see, in the worst cases where collision happened the frames will sent during three beacon interval only so this will guarantee end to end delay.

The simulation environment has considered a maximum frame length of 50 bytes and beacon length of 256 ms. Two performance metrics are considered which are end to end delay and power consumption. The results show that using adaptive method the collision rate is between 2.8% to 3.5%. If non adaptive method is used the collision rate increases to 16.5%.

In conclusion, UA-MAC designed especially for applications that use control commands and require bounded end to end delay. It can also be used for other applications like real time communication and emergent calls.

To conclude, we provided in-depth analysis of those with adaptively attitude protocols since they take in consideration more than one challenge to solve and serve various applications. This has been achieved either by combining contention based and contention free mechanisms like these studies [14, 15, 18], or by designing the scheme in specific way [17] to allow for adaptability behaviour. All contention free schemes adopt TDMA mechanisms while contention based schemes adopt either CSMA or Aloha. Additionally, various parameters are considered in the adaptive MACs like reliability (reducing packets loss), power consumption, end to end delay, fairness of data transmitted and emergent data transmission.

5. CONCLUSION

Wireless Home Automation Networks and smart home applications have their own challenges and requirements that should be satisfied by the MAC layer protocols. The aim of this paper is classifying the general smart home applications into categories and then identifying the main requirements and challenges regarding the MAC layer protocol in each category in the smart home environment. As we have seen from the reviewed applications and analyzed requirements, we noted the most important issue that need to be considered in MAC protocol design is the adaptability since the nature of WHAN is very wide and contains large amount of various applications. Moreover, we studied some adaptive MAC schemes and conclude that adaptability of the protocol means the ability to convert its working mechanism in order to satisfy the needs of multiple applications and that generally can be achieved by giving different priority levels of the transmitted data.

As a future work, based on the requirements collected from this research work and based upon the analysis and the requirement of adaptability, we will select the following three schemes as promising solutions that can be enhanced to meet most of the requirements of smart home applications:

- Context Aware protocol for WBAN (CA-MAC)
- Delay Controllable (DC- Protocol)

- User Adaptive MAC (UA-MAC)

So in the future we will investigate these selected schemes and do in depth analytical evaluation study on them in order to design and propose new adaptive MAC protocol that serves different priority levels for smart home applications by suggesting improvement on these selected schemes by combining their useful mechanisms and identifying their main weaknesses to be avoided in the design of the new MAC protocol. Then experimental evaluation of the proposed MAC scheme will be presented in our next work.

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