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SENSOR NETWORK FOR PATIENT MONITORING

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ABSTARCT:

Wireless patient monitoring fulfill the requirement of providing better health care services to an increasing number of people using limited financial and human resources .Remote health monitoring is provided by the wireless body area network(WBAN).In health monitoring there are two major challenges which are sustainable power supply for body sensor network(BSNs) and Quality of Service(QoS).To address these challenges this seminar proposed an architecture that allows virtual groups to be formed between devices of patients, nurses and doctors in order to enable remote analysis of WBAN data. Through an underlying environmental sensor network the WBAN data gathered are transmitted to the virtual group members.

Keywords: *wireless sensor network; body area network; remote health monitoring.*

INTRODUCTION

Smart environments represent the next evolutionary development step in building, utilities, industrial, home, shipboard, and transportation systems automation. The smart environment relies first and foremost on sensory data from the real world. Sensory data comes from multiple sensors of different modalities in distributed locations. The smart environment needs information about its surroundings as well as about its internal workings; this is captured in biological systems by the distinction between exteroceptors and proprioceptors. The challenges in the hierarchy of detecting the relevant quantities, monitoring and collecting the data, assessing and evaluating the information, formulating meaningful user displays, and performing decision-making and alarm functions are enormous. The information needed by smart environments is provided by Distributed Wireless Sensor Networks, which are responsible for sensing as well as for the first stages of the processing hierarchy. The importance of sensor networks is highlighted by the number of recent funding initiatives, including the military programs, and NSF Program Announcements.

A sensor network is a group of specialized transducers with a communications infrastructure intended to monitor and record conditions at diverse locations. A sensor network consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable. Every sensor node is equipped with a transducer, microcomputer, transceiver and power source. The transducer generates electrical signals based on sensed physical effects and phenomena. The microcomputer processes and stores the sensor output. The transceiver, which can be hard-wired or wireless, receives commands from a central computer and transmits data to that computer. The power for each sensor node is derived from the electric utility or from a battery. Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. WSNs were initially designed to facilitate military operations but its application has since been extended to health, traffic and many other consumer and industrial areas. A WSN consists of anywhere from a few hundreds to thousands of sensor nodes. The ageing population will lead to increased healthcare cost as care for the elderly is much more expensive than that of other age groups. Electronic Health (eHealth), which integrates information processing and communications technologies into traditional medical services, emerges as a promising approach to improve healthcare efficiency. Pervasive health monitoring is an eHealth service, which plays an important role in prevention and early detection of diseases. [Ivanov (2012)]

Various research initiatives have been setup to develop new solutions to help enhance and support more efficient and cost effective health care systems because of increased pressure in healthcare industry due to the ever increasing population and reduced funding from governments. One approach toward this is to enable more efficient monitoring techniques, which includes: 1) the examination of patients based on their criticality, which in turn enhances doctor's time efficiency in examining patients, and lowers queues in emergency rooms, and 2) accurate monitoring of patients conditions and trends over a period of time. Wireless body area networks (WBAN) provide an opportunity to allow monitoring with such capability and high precision. But it arises some

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challenges these includes the ability to extract information from WBAN and view this virtually between medical officers, the ability for medical officers to set requirements, where these requirements can drive the operation of the sensors (e.g. gather ECG data for patient X, every 5 ms; prioritize data from critical patients), and the ability for WBAN sensors to cooperate in a scalable and distributed manner to support the requirements of above Challenges. These challenges are addressed by the architecture which is separated into two parts. The Virtual Group Enabler (VGE), forms virtual groups between patients, nurses, doctors and environmental sensors. These groups allow data from WBANs to be analyzed remotely by doctors and nurses; the virtual groups can be modified and changed depending on the patient's condition or requirements from the medical officers. The change in virtual group configuration can be easily adjusted through high-level policies. In the environment which is densely populated with sensors, where these sensors are networked and can allow WBAN and virtual groups to interact. To accommodate such interaction the underlying wireless technology has to provide a fast reliable connection and needs to be energy and cost efficient due to the necessity to accommodate large number of patients. In order to be easily coupled with a policy management system the proposed system requires a certain degree of adaptability where the policy management system can handle high-level changes that might be required by the medical officers. A cooperative multichannel MAC protocol with adaptive routing is presented in the second part of the proposed architecture. The proposed architecture goes further by allowing the virtual groups to use policies to specify behavior and cooperation of sensors both on WBAN and in the environment. Through high-level policies, medical officers can adjust performance of the system in the event that quality of sensor readings is poor due to high losses. The proposed approach has been evaluated through a series of simulations. [Warren (2005)]

ARCHITECTURE

The information collected by the low data rate sensors is gathered by a device known as body area network controller (BNC). The on-body sensors are connected to the BNC in a simple star network topology using the on-body interface. The BNC can be devised as a personal digital assistant (PDA) that executes a MAC protocol, for example, in order to ensure that all the sensors transmit their information in an organized and fair way. For in-home healthcare, the BNC can display several basic vital signals such as temperature, heart rate (HR), blood pressure (BP), and oxygen saturation (SpO2).

I. Energy Harvesting in Wireless Sensor Networks

Energy harvesting is a promising technology for many sensing applications, especially for those in which the battery substitution is impossible. Energy-harvesting enables a new mode of operation, namely the energy-neutral mode, at which the system uses only as much energy as obtainable from the environment. Due to the low recharging rates and the dynamics of energy harvesting process, it is a challenging task to provide services without break caused by exhausted battery. The authors computed the lexicographically maximum data rate for each sensor, under the restriction that no sensor will ever run out of energy. The paper outlined several systems aiming at generating electrical energy by passively tapping a variety of human body sources and activities. The energy harvesting process is modeled by a Markov chain, based on which the probability of event loss due to energy run out is calculated. Here developed an efficient transmission strategy for BSNs with energy harvesting capabilities, considering the trade-off between the energy consumption and packet error probability. First, model the power use of a sensor and examine the relationship between the source rate and the lifetime of the sensor. Second, study the resource allocations of the health monitoring system consisting of three hops of communications, here work demonstrates the following novelties: 1) analyze the relationship between the source rate and the uninterrupted lifetime of the sensor, and optimize the source rate of each sensor to reduce the rate actuation under the requirement of the nonstop service; 2) jointly optimize the transmit power and the transmission rate at each aggregator in an eHealth location to provide QoS guarantee to the delivery of data streams. In a health monitoring system with body sensor networks, the data streams collected by the sensors are delivered to the medical server in real time. The back-to-back transmission path of data streams is illustrated in Fig. 1.

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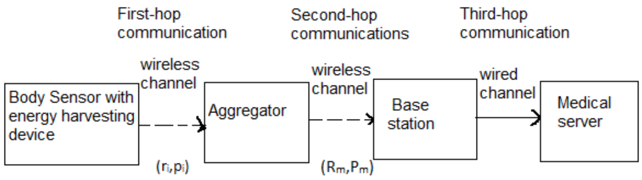

Figure 1. Transmission Path of Data Streams in the Health Monitoring System

The end-to-end delivery of data streams consists of three hops of communications: 1) the first-hop communications, which occur from a body sensor to the aggregator via wireless channels, 2) the second-hop communications, which occur from an aggregator to the base station via wireless channels, and 3) the third-hop communications, which occur from the base station to the medical server via wired channels. The objective of health monitoring systems is to provide a sustainable and high-quality service to subscribers. A high-quality service is determined by the source rate from a sensor, and the packet loss rate (PLR) and the delay of the data stream over the transmission path. The delity of the original signals is determined by the source rate. A higher source rate from a sensor can represent the original signals at a higher quality. The data streams collected at the sensors are delivered to the medical server for further analysis and decision making. QoS metrics, including PLR and delay, are used to measure the delivery quality. In real-time health monitoring systems, a lost packet or an excessively postponed packet may cause a fatal accident. Therefore, both sustainable power supply and QoS guarantee are important for health monitoring systems. The sustainability and the high quality are two mutually dependent components. There are two trade-offs in the health monitoring system. The first trade-off is the interdependence between the sustainability and the high quality. A sensor can extend its life span by generating a lower source rate, which, however, degrades the quality of the signals. The second trade-off is the interdependence between the source rate and the QoS. Higher source rates from sensors may cause more congestions and more transmission errors along the transposition path, which cause a higher PLR and a higher delay for the data streams.[He and Zhu(2011)]

II. Steady-Rate Optimization Problem

This section described the connection between the source rate and the lifetime of the sensor. Each body sensor has a limited battery capacity. Assume that an energy harvesting device is employed at each sensor to refill the energy from the environment. The dynamic energy harvesting process leads to active energy replenishment at each sensor. In order to maintain an uninterrupted service, each sensor needs to correct its source rate over time accordingly. In a health monitoring system, a steady source rate is desired. Therefore, here formulate the steady-rate optimization problem, which minimizes the rate actuation under the constraint of the uninterrupted service. Each body sensor captures the physiological readings and packetizes them into packets, which are transmitted to the aggregator. A chief difference between body sensor networks and other wireless sensor networks is that BSNs may contain critical readings, which should be picked out and then treated with a higher priority. Therefore, implement the mechanism of differentiated treatment at each sensor. The differentiated behavior consists of two steps: packet categorization and package scheduling, as shown in Fig. 2.

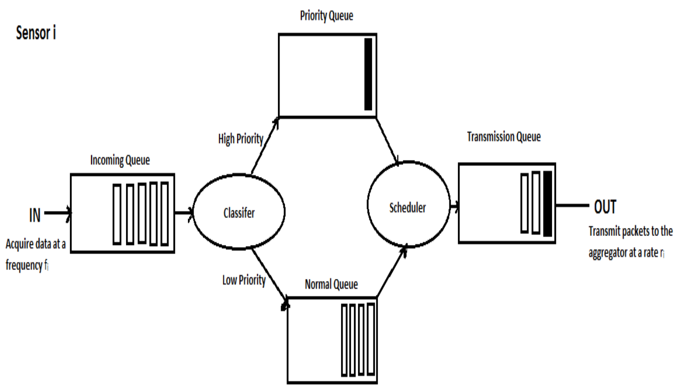

Figure 2. Packet Classification and Packet Scheduling at a Sensor

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The data are acquired by sensor i at a frequency fi. Increasing the frequency fi of data acquisition can lead to an increased source rate. A physiological reading is packetized into a packet, and then stored in an incoming queue. At the step of packet classification, a classifier classifies the packets into one of the two classes: prioritized packets and normal packets, based on the preset thresholds at each sensor. If the physiological reading is in the normal range which indicates that the patient is in a normal condition, the corresponding packet will be classify condition, the corresponding packet will be classified into a normal packet. On the other hand, if the physiological reading is in the abnormal range which indicates that the patient is in an irregular condition, the parallel packet will be classified into a prioritized packet. The prioritized packets will be put into a precedence queue, while the normal packets will be put into a normal queue. At the step of packet scheduling, a scheduler first chooses the packets in the priority queue and puts them into the transmission queue. Only when the priority queue is empty, the packets in the normal queue can be scheduled for moving into the transmission queue. The transmission order of a packet is determined by the classifier and the scheduler. The packets in the transmission queue are placed based on their transmission orders. In other words, the packets to be transmitted earlier are placed in the front of the transmission queue. The sensor transmits the packets in the transmission queue to the aggregator in a First In First Out (FIFO) ordered into a normal packet. On the other hand, if the physiological reading is in the abnormal range which indicates that the patient is in an irregular condition, the corresponding packet will be classified into a prioritized packet. The prioritized packets will be put into a priority queue, while the normal packets will be put into a normal queue. At the step of packet scheduling, a scheduler first chooses the packets in the priority queue and puts them into the transmission queue. Only when the precedence queue is empty, the packets in the normal queue can be scheduled for moving into the transmission queue. The transmission order of a packet is strong-minded by the classifier and the scheduler. The packets in the transmission queue are placed based on their transmission orders. In other words, the packets to be transmitted earlier are placed in the front of the transmission queue. The sensor transmits the packets in the transmission queue to the aggregator in a First In First Out (FIFO) order.[He and Zhu(2011)]

III.Overall Architecture

The overall system architecture is illustrated in Fig. 3., with the fundamental goal being to cluster or form groups that provide an competent PM mechanism in the acute health-care field. Services run on each member's device within the group. The data gathered from the WBAN sensors on each patient are distributed to the group member's services. As illustrated in Fig. 3, environment is densely populated with environmental sensors that provide data sources, as well as allowing WBAN to interact and deliver data between virtual group members. The architecture of the VGE includes the Group Management Service (GMS), Medical Data Recording Server (MDRS) (which houses patient’s problems), the Policy Engine (PE), and the devices of the medical officers, WBANs on patients, and environmental sensors. GMS and PE when combined provide the means to statically and vigorously build groups between any deployed services. It also provides a mechanism through which the behavior and management of these groups can be controlled, where this control is from a messaging process.

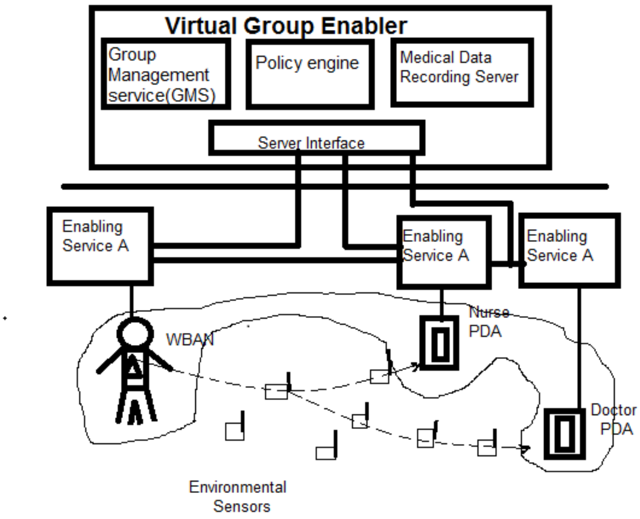

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Figure 3. Overall Virtual Group Enabling Architecture

I.Virtual Group Enabler
Group Management

Each group instance is controlled by its own configuration and actions policy, where policies are developed from the concept of policy-based management systems. Policies are used to handle groups under two different aims, 1) as an aid when configuring and building groups 2) as a way to control the behavior of a particular group. The policy has the following structure Event, Condition, Action. The Event element is an occurrence of an important message/occurrence that can be used to trigger the evaluation of conditions. Condition is an aggregation of individual conditions which define the prerequisites for resulting actions, while Action represents the necessary actions which need to be taken if the condition evaluates to true. When specific instances of the three are combined into one overall entity occasion, Condition, Action, it is known as a PolicyRule. A orientation representation of services within one single group and an example of its governing policies is specified in Fig.4. This figure shows the different stages during group formation and group expansion. Stage 1 highlights the four different services that exist, with no groups formed. The transition to stage 2 is that a new Patient Monitoring (PM) group is formed between the patient (with his/her WBAN) and the MDRS that is receiving all readings for past recording of data. At this stage the PM policy is governing the group. A HypertensionAlarm is detected by the PM policy and this transitions the system to stage three where a nurse (N) is added to the group. Once this occurs the Quality of Health Monitoring (QoHM) policy and its related Data Reliability (DR) policy become active in the overall governance of the group. The QoHM policy defines the perception quality that doctors or nurses have on the sensor readings presented on their device. The sensor readings maybe affected by packet loss along the data routes from the WBAN. Medical personnel can provide a QoHM level between 0 and 5 for each measurement type, with 5 being the highest quality. This is a similar concept to Mean Opinion Scores that are used to maintain the quality of experience (QoE) for multimedia streaming . The HyperTensiveHighPriority alarm is the event, which triggers the system into stage 4 and the inclusion of a doctor to the PM group. The application- specific services deployed on each device are illustrated in Fig. 4.

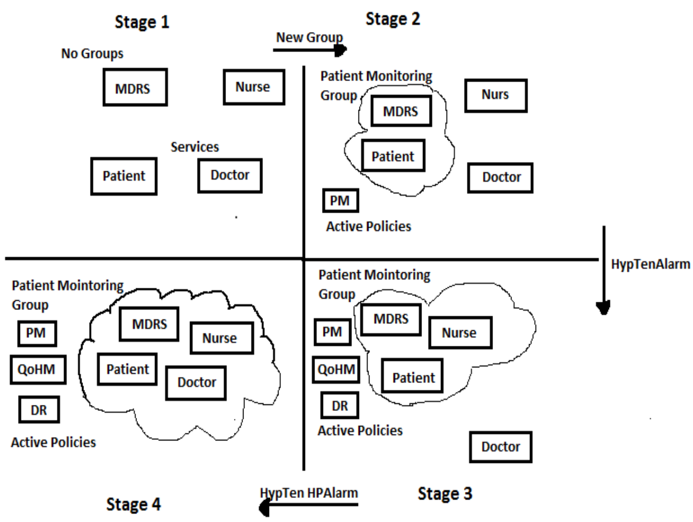

Figure 4. Stages of Group Formation and Expansion

These service instances will become part of the PM group that in turn will be governed by different policies. The communication between the member's services will be performed through the environmental sensors, as shown in Fig. 5.

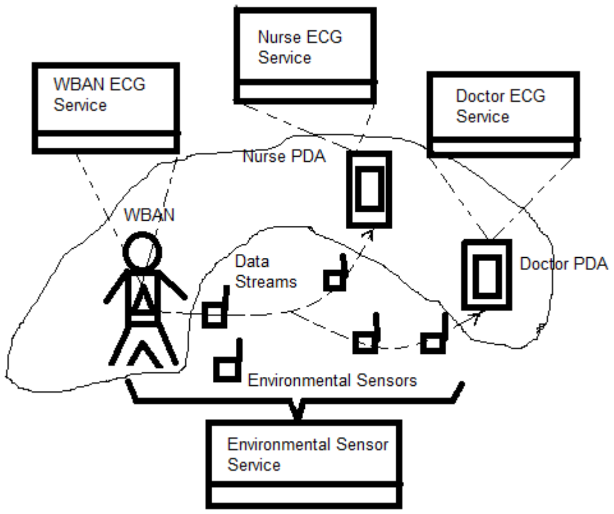

Figure 5.Group Service Interaction via Environmental Sensors

Through these services and their intercommunication, we address Challenge (i) of the introduction, namely the ability to share PM data between medical officers. We selected this mode of communication overcommunicating via a wireless access point (e.g., WiFi) because: 1) access via WiFi from a portable or sensor device could lead to higher energy consumption 2) environments will contain sensors which users of all types can interact with (an environmental sensor could also be a group member, in order to provide a richer dataset), and 3) this form of communication is distributed and has less single points of failure in comparison to WiFi access points. However, failures of environmental sensor nodes will only require new routes to be formed from neighboring sensors. Fig. 4. Illustrates in more detail the relationship between policies and deployed group instances in conjunction with the link to the underlying MAC and routing technologies. The background of the figure is ECG measurement. A group instance is created by issuing a request to the GMS. The details of that group instance are stored in GMS for the lifetime of the group.

Group creation allows for the assignment of one or more policies to the new group, where this mapping also resides in the GMS. The configuration policy determines the formation of the group by considering context problems of each actor (e.g., a specific type of condition may require a particular specialist to join the group). The behavior policy impacts the run-time actions that the individual members must take within the context of the group. As illustrated in Fig. 5., the policies governing each group instance will have a hierarchical structure with different levels (medical officer levels as well as low-level sensors). The Medical Officer Level contains policies that are associated with the patients within the groups (PM policy), as well as the QoHM policy. The Data Reliability policy is the governing policy at the lower sensor level. The combination of high and low-level policies at the different levels underpins adaptive group behavior. The formation of the group is based on the addition of a medical officer (e.g., nurse or doctor). The selection of which medical officer should be included over another (i.e. select nurse A over nurse B) is based on their load. The load in this case is defined as the number of PM groups that the medical officer is a member of. The medical officer involved in the smallest number of groups will be selected. . [Ivanov (2012)]

IV.Wireless Transmission Technology

While the previous sections described the policy-based administration system of our proposed architecture, this section will present the adaptability mechanisms of the underlying wireless sensor networks that can cater and support changes from the high-level policies. Due to the low cost and energy efficiency requirements, IEEE 802.15.4 is selected as the underlying communication technology. Therefore, all sensors (including the WBAN sensors) are single half-duplex transceiver devices and can be tuned to many channels at the MAC layer. Communication between members of the groups is through the sensor networks and supported by the MAC and Network layer technologies presented in this section.[Ivanov (2012)]

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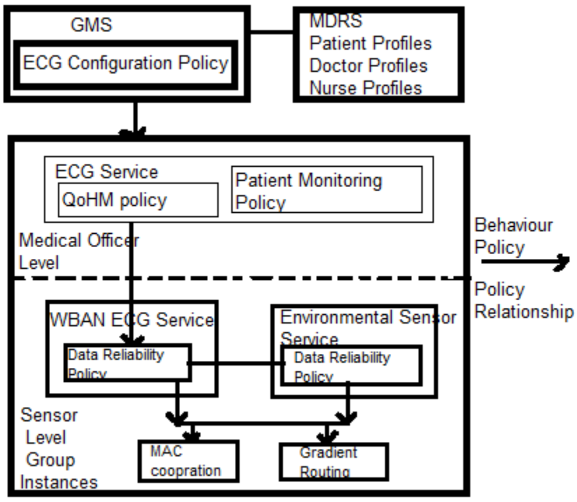

Figure 6.Overall Group Instance Policy Perspective identifying the relationship to both MAC and routing technologies

V. CAM-MAC-ARCB Protocol

Single MAC layer channel usage of IEEE 802.15.4 design significantly limits the capacity of the system due to performance dreadful conditions in case of large patient numbers coupled with the group communication. Therefore, considering the implementation costs, we have chosen single transceiver multichannel protocols to be used at the MAC layer. Due to high risks of multichannel collisions, these protocols are required to exhibit a towering degree of cooperation. We have developed a cooperative negotiation protocol for multichannel MAC known as CAM-MAC-ARCB, which extends from the original CAM- MAC protocol. This section provides an overview of the cooperation process. An illustration of cooperation at the MAC layer is illustrated in Figure 7.

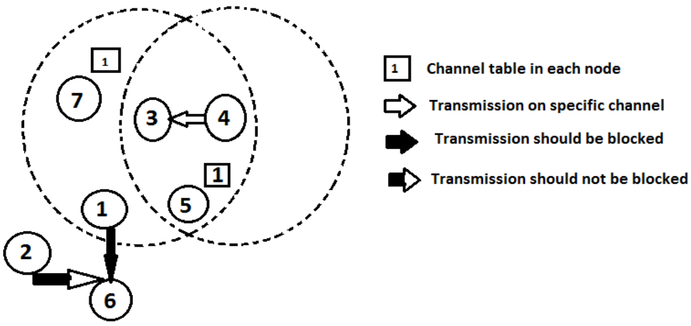

Figure 7. CAM-MAC-ARCB negotiation process

In the event that a sender (node 4) needs to broadcast a packet, a negotiation is initiated with the receiver (node 3) on the control channel. The negotiation will include information on the candidate data channel that the sender wishes to use. This cooperation process will be overheard by all the neighbors (nodes 1, 5, and 7), and if the sender and receiver agree on this channel, this in order will be stored by all neighboring nodes. In the event that a new pair of nodes (nodes 2 and 6) decide to negotiate on this same data channel, the neighbors will all veto this negotiation, since it has already been taken by a previous pair of nodes within the vicinity. In the case of the original CAM- MAC protocol, node 1 will veto the negotiation of nodes 2 and 6, even though the nodes are out of range from nodes 3 and 4. However, CAM-MAC-ARCB avoids unnecessary vetoing process through a virtual topology inferencing process. This in turn leads to higher throughput between the sensor nodes. . [Ivanov (2012)]

VI.Gradient-Based Routing

Uneven distribution of patients, medical personnel, and presence of additional monitoring devices (e.g., ZigBee cameras) lead to varying network loads within the environment. In such cases group message delivery through highly loaded network regions may lead to QoHM degradation. In order to avoid this we use gradient-based routing technique that avoids highly loaded regions [see Fig. 8(b)]. The importance of using weight receptive routing becomes higher when the number of patients increase, as patients may gather around certain locations leading to certain parts of the network being overloaded. Therefore, to get better communication reliability for intergroup communication, the solution uses a cross-layered gradient-based routing technique built over the CAM–MAC–ARCB co-operation . The technique stretches across Data Link and IP layers as presented in Fig. 8(a).

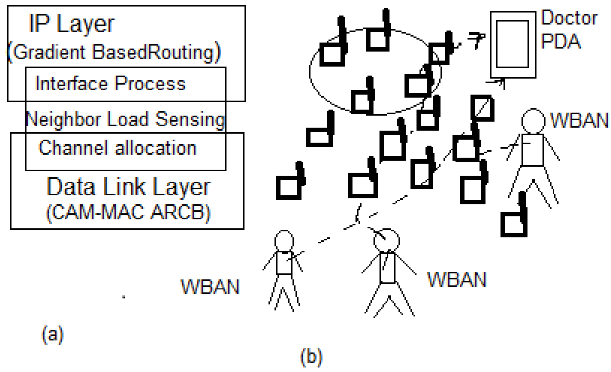

Figure 8. Adaptive routing solution: (a) cross-layered integrated solution and (b) routing around high-network load regions with different priority

The constant monitoring of ongoing negotiations at the MAC layer allows each network node to estimate its own link capacity and load. This inference is further fed to the IP layer, where the routing process determines the path by creating a gradient field within the environment. Therefore, at each node *i* of the network the gradient field $G_{n,d,n \to I}$ represents its capacity for flow routing from node *n* to destination *d* and is represented through the following" Eq. (1)":

$$G_{n,d,n \to i} = \gamma \cdot \Phi_{i,d} + (1 - \gamma) \cdot h_{i,d} \qquad (1)$$

where $h_{i,d}$ represents the normalized hop count from node *I* to destination *d*, and the $\Phi_{i,d}$ denotes the capacity of the node to route a flow. The routing process selects the path traversing through nodes with maximal gradient field values in order to increase chances of arriving at the destination. Therefore, $\gamma \cdot \Phi_{i,d}$ is a linear load-based correction of the shortest path, where parameter γ represents reliability of the established routes and determines how far routes may divert from the shortest path while avoiding highly loaded regions of the network. The strength of this multihop routing approach for our monitoring solution, is that different paths can be taken for different types of data. For example, intergroup message can be performed through longer routes, while WBAN data could be transmitted through shorter routes. The selection and strategy to increase γ is governed by the QoHM policy, where each γ corresponds to the reliability levels. The facility of sensor devices for load-sensing through constant monitoring of MAC layer negotiations jointly with the gradient-based routing address. [Ivanov (2012)]

VII.Intergroup Communication

In order to evaluate cooperation efficiency at the MAC layer, this section compares performance of the CAM-MAC-ARCB and CAM-MAC, with respect to varying group sizes and intergroup communications. The reproduction scenario represents a hospital coming up area. Each patient is equipped with a WBAN, where the patient condition information is aggregated by the WBAN sinks and occasionally reported to a doctor, nurse, and MDRS server via any of the gateways. The patient sensor readings are delivered via environmental sensors or sinks of other WBANs. During the reproduction the number of patients with failing conditions will slowly increase, resulting in increasing number of virtual groups formed. Also the Packet Loss and Packet Delay occurs as the number of virtual groups increase. The increase in the number of virtual groups will result in increased data sent to the doctors and nurses, which in turn maps to overall system load boost. Although both protocols display good cooperation performance, CAM-MAC-ARCB clearly outperforms CAM- MAC.

The performance enhancement of CAM-MAC-ARCB over CAM-MAC protocol is attributed to the ability of CAM-MAC-ARCB sensors to learn and infer from the negotiation process of their neighbors. This in turn minimizes the amount of RCB performed by the nodes, which in turn reduces the waiting instance prior to packet transmission. Since CAM-MAC has to spend more time on a packet transmission during the waiting period, this also leads to higher power consumption of WBAN sensors compared to CAM-MAC-ARCB. Due to low mobility of the patients and sequential appearances of new patients in our scenario, the technique nearly eliminates cases that can lead to RCB. In order to evaluate the cross-layered gradient-based routing with respect to unreliable virtual groups, we analyzed High and Max reliability values in comparison to Standard reliability. The evaluation exploits the simulation scenario described earlier with an addition of four ZigBee wireless cameras used for PM. In our evaluation, the standard routing protocol is the AODV protocol. Exploiting Max reliability increases the capacity of the newly well-known patient-nurse and patient- doctor communication routes to traverse away from highly loaded areas. In the case of 20 groups being formed during the simulation, using gradient-based routing of Max reliability value improved packet delivery ratio by 8 percent and caused 16 percent power use in comparison to Standard dependability.[Ivanov (2012)]

CONCLUSION

WBAN provides a new opportunity for monitoring healthcare patients. The wireless technology propose the VGE architecture for virtual group formation that allows medical personnel to continuously analyze PM, and fine tune changes in sensor behavior through high-level polices. The dynamic policy changes performed by the medical officers can improve the sensor readings of critical patients when performance of the network degrades. This technology also proposed a new metric called QoHM, that allows medical officers to provide feedback on the quality of sensor readings by setting their preference through policies. The hierarchical policy structure can allow doctors to specify their QoHM threshold, which in turn will go down and configure the cooperation and routing behavior of the sensor nodes. The proposed solution is evaluated through simulation.

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