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Optimal Data Transfer From Wearable Body Sensors

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Abstract: **With increase in health consciousness among people, wearable devices have gained in size and complexity of data transfer. The transfer of critical data from sensors over the wireless medium involves a careful analysis of the location of the destination and the available bandwidth to reach the same. This non trivial real-time task is performed by the underlying middleware service by exploiting the resources based on the priority In this paper, an architecture of the middleware making use of information feedback is provided.**

I. INTRODUCTION

The number of sensors used in a body area network[9] is ever increasing; often require them to transfer data in real time. The revolution in IoT technologies has resulted in wide usage of these wearable devices. This puts heavy traffic of the sensor network calling for efficient mechanisms to share the available bandwidth, generally involving the constrained medium of free space. Sometimes, when the patient is in critical state or in Intensive care unit, the real time transfer of vital parameters is requires. I.e. more data is to be transferred. In those situations, the available bandwidth is also high and provided by the hospital infrastructure. On the other hand, when the patient is outside of the hospital, the available bandwidth is low, under the mercy of public network and the data to be transferred is also low, as the condition is not critical.

The architecture provided in [5] gives an automated remote monitoring mechanism through sensors. A typical setup consists of a sensor, communication apparatus, central unit and the communication channel. The central unit is placed in the cloud.The sensor captures the vital data from the body automatically and transfers the same over to a remote central unit over the available mode of communication.

The data transfer between the wearables and the cloud is required to be optimal as explained in [6]. In this paper, a noveldatatransfer scheme based on the information feedback is provided.

A continuous monitoring or real time data from the sensors is not always required especially when the patient is doing well. In such cases, based on the case history, sampled and stored data may be transferred. The sampling rate as well as the amount of data that gets transferred depends up on the condition of the patient as well as the available resources.

The proposed method provides a mechanism for sensors to automatically switchover the data from compression mode to non compression mode depending up on the location and condition of the patient, adapting smoothly for the ambient that includes the available infrastructure to carry the data.

Table I . Automated decision making

Patient condition	**Location**	**Band width**	**Bit rate of data**	**Scheme**
Normal	Outside hospital	Less	Less	Compress
Serious	Outside hospital	Less	More	Do not compress. Use collaborative network
Normal	Inside Hospital	More	Less	Compress
Serious	Inside Hospital	More	More	Do not compress. Hospital infrastructure supports this rate

The rest of the paper is organized as follows: The section II provides the proposed architecture that calls for adaptively changing the bitrates as well as the acquisition data rates from the sensors depending up on patient condition and location. Section III provides the data processing method and section IV provides the need of network feedback information to achieve the same. Section V summarizes the concept.

II PROPOSED ARCHITECTURE

The features of the proposed architecture include

- Data compression when required
- No compression to support the requirement of real time data
- Varied sampling intervals depending on patent condition and available bandwidth.

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- Formation of a collaborative adhoc mesh network with other patients and provide required infrastructure in case of emergency

Based on the location and condition of the patient , i.e. in the intensive care unit of a hospital where the patient has serious issues or outside of hospital where the patient is leading a normal life, the sensors compress or do not compress the data. The sampling interval also varies.
The proposed technique is useful for body area networks involving wearable sensors of all kinds.
The mechanism provided here is designed for the people who are either sick or potentially under health risk (for example, aged but healthy human say typically 60+ years) who are required to be monitored continuously but healthy enough to stay outside the hospital. For example, a patient with high blood pressure around 160/100 aged 50 years, having suffered a mild heart attack 2 years back is prone for another attack. Although he can lead a normal life, he is under health risk and needs to be monitored. Also, he can not be always located inside a hospital. When conditions become abnormal, for e.g., the blood pressure or heart beat changes rapidly he needs immediate medical attention to prevent a fatality. Only a round the clock monitoring system can help.
The blood pressure values of 160/100 generate about 16 bits+ 2 CRC bits≈20 bits. Considering a 8 bit header/label (8 bits can handle futuristic 256 sensors over the body) it adds to 28 bits as shown in the figure 1. One of these 256 sensors could be for heartbeat. The last 4 bits are reserved for packet ID or (and) timer stamp.
Heartbeat measurement could be contained in the above packet. The heartbeat/min, a number to be generated over duration of 1 minute requires 7 bits for representation. One bit may be added for CRC and one byte as the header, resulting in 16 bits. This is lesser than the 28 bits already calculated above
When ECG data is also available (heart beat may not be required now), it requires variable number of bits depending up on the compression.Multiple packets with appropriate packet numbers may be used to transfer this data.Typically the sampling rate is 200 Hz with 8 bits per sample resulting in 1.6kbps data. This data may be compressed by a factor of 4 with fairly accurate SNR.
It is important that the SNR is to be highest during critical condition (such as when the patient is about to get the attack). Determination of critical condition is explained later.
Under the normal condition (even a blood pressure of 160/100 may be normal for the patient considering the case history) the parameters such as blood pressure and heart beat are sampled at the rate of twice a day. Parameters such as ECG may sampled once day as shown in figure 2. The sampling time is controlled by the RTC. The captured data is buffered, processed and packetized before transmission. The process & packetization unit is shown in figure 3.
The transmission depends up on the patent location and condition as indicated in the table. The ECG, the bulk data generator, generates data at the rate of 400 bits/sec. This data may be buffered and transferred to the data analysis portals /cloud server in non real time at a reduced bit rate. E.g. a 1 minute ECG data may be transferred in 30 minutes and collated at the receiving end.
Today mobile devices support data transfer over public network. The data from sensors may be collected by the mobile device like cell phone over Bluetooth protocol. After getting this data (maximum of 1600 bits per second, say) two things are to be done

i) Ascertain patent condition
ii) The location i.e. public network or hospital infrastructure network.

It happens in the transfer unit as shown in figure 4. The figure 5 provides location estimation by running the existing GPS/CDMA and wi-fi protocols. i.e the patients location of inside hospital or in the public network is determined. The GPS/CDMA stack requires a SIM to be provided by the service provider. The cell phones can also be used as the GSM/CDMA or wi-fi protocol stack. Finally, rely on the mechanism of wi-fi or GSM/CDMA maps to the conditions in the table.
The patient condition may be decided by comparing the captured values with the previous set of values (record) as well as the case history specific to the patent entered by the doctor (for example, the Blood pressure of 140/110 may be normal for the patient). The previous set of values is stored in mobile device.
If any of the parameters (heart beat, Blood pressure…) is abnormal for the patient (the thresholds are to be set by the doctors during hospital visits based on case history) other parameters are also captured immediately and more frequently, depending on the deviation from the allowed range. For example if the blood pressure shoots to 165/100 the frequency may be doubled. If it increases further in the next reading, then hour by hour or minute by minute sampling may be required. Thus it depends upon both trends in the change and history.

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The location information is got by sensing the RF on the mobile device. It happens through Location estimation. Finally a decision, as shown in the table, is made by the decision unit.
Outside the hospital, the mobile device behaves exactly like the mobile phone. Instead of voice/multimedia data, the parameters from the sensor get transferred to a portal/server over the public network. Standards such as Upnp, CE-HTML make it feasible. The data gets consolidated or trimmed or archived (or even deleted) based on the condition of the patent.
When the patient visits the hospital, the mobile device gets attached to the hospital network exactly the same way a Bluetooth enabled device gets attached to the Pico net. The Pico net is given priority in case the device still has access to the public network.
On the other hand, when the patient is critical i.e. when the ECG is to be monitored continuously, it is not advisable to go for compression at all. A real time, highest quality ECG requires 12 leads, 11 bits per sample and 1000 samples per second, generating 132Kbps. This is another extreme, typically generated by huge ECG machines in the hospitals.
For remote monitoring and access the patient condition, 3 leads with 10 bits per sample and 500 samples per second are sufficient (as per American heart association).This generates 15kbps data. This data has to be transferred in real time without compression. Today's GSM/CDMA technology already permits this data rate.
When high bitrates are to be transferred in real time, in future, (involving more sensors such as Ultrasound image, Blood Sugar level or the ECG with high quality mentioned above, using a portable device) the mobile devices can form collaborative network to share the resources.
The mobile device transfers data with higher rate. The collaborating devices catch this data, improve the SNR and retransfer. (The SNR deteriorates if the data rate is increased) The collaborating devices lend their share of spectrum/channel for this mobile device, gets its data (in pieces), improve the SNR and retransmit the same. The device discovery happens through a standard protocol such as Upnp+

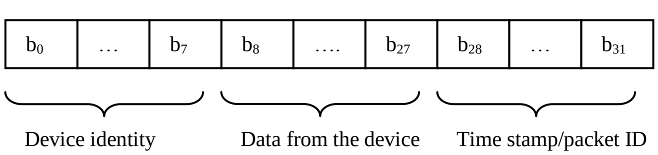

Figure 1 data format

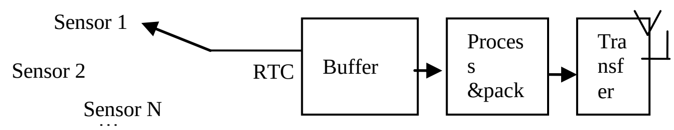

Figure 2 Data acquisition

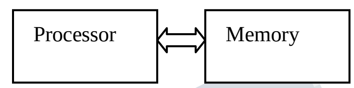

Figure 3 Process & packetiser unit

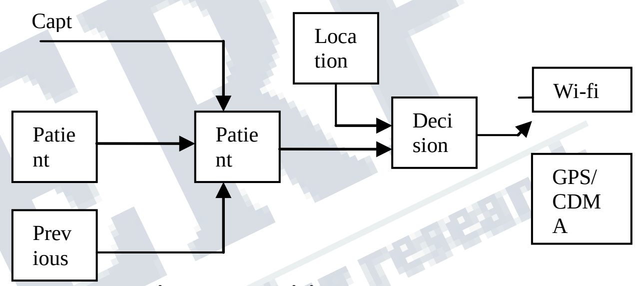

Figure 4, Decision system

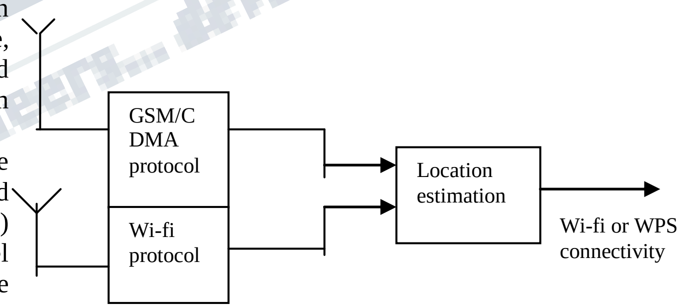

Figure 5 Location estimation

III SIGNAL PROCESSING FOR HANDLING THE DATA

Data arrival at multiple rates from the sensors is a major problem in the acquisition system, calling for multi rate sampling. The problem gets complicated when several such data have to be fused. Usage of time stamps helps in

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asynchronous fusion. In this case real time data will not be available. Still, the appropriate data will under go fusion with the help of time stamps.

In the place of raw data, the processed data may be transferred depending up on the application.

Many middleware programs are available to perform these types of operations and embedded in to the sensor. Most of these programs are not capable of data acquisition and only perform data analysis. These data analysis programs are designed to work in conjunction with data acquisition programs. The cost of these programs is usually less than for programs combining data acquisition with data analysis.

This class of software programs can perform processing on either real-time data(concurrent processing) or stored data(post processing).

Most of these programs support standard mathematical calculations of arithmetic, trigonometric, mathematical, logical and basic statistical functions.

IV TRANSFER OF THE DATA

The wireless sensors and the server form an adhoc network making use of a combination of fixed and mobile infrastructure. Bandwidth in such a network is critical as the RF power is involved.

The middleware driving the applications has to get the information on the available resources several time steps ahead in order to manage the available bandwidth effectively. The applications can adjust the data rates so that the resources in the network do not get flooded and lead to congestion. The set up is shown in figure 6.

The algorithm random early Detection (RED) that provides informationon congestion status of the network, available as the probability of packet drop, has been described in[7]. When this feedback signal is predicted several time steps in advance, the data sourceshould get sufficient time to adjust the data rates. The proposed method[8] provides prediction to the RED signal through a new class of predictor, the differentially fed artificial neural network

V CONCLUSION

The wearable sensors used in healthcare applications are to switchover to different networks depending up on the geographical location and physical conditions of the patient.

The increased mobility in network results in frequent handoff and poses synchronization problems. Precise time signals are required to assure uninterruptible handover.This is required to provide the right type of connectivity between the patient and the caring unit. Availability of bandwidth for the data transfer is critical for this switchover. Availability of the knowledge on the congestion status of the resources of the network ahead of time would be helpful for the controlling middleware to acquire and transfer the right quantum of data.

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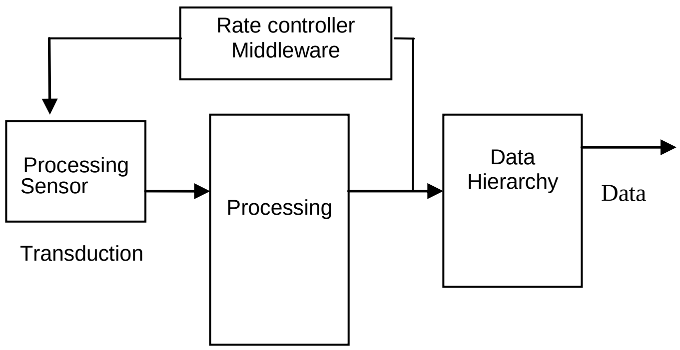

Fig 6. Data acquisition and transfer with feedback

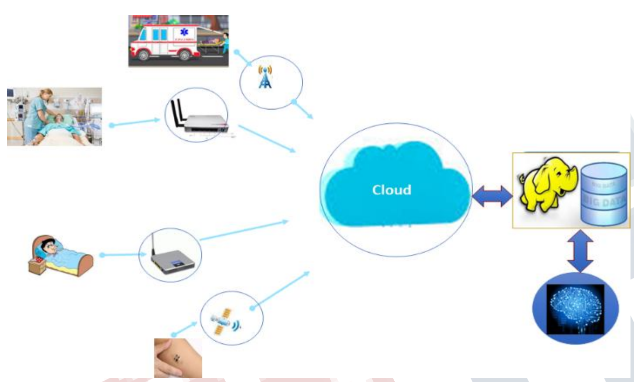

Figure 7. Wearable Healthcare devices connectivity to the cloud

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