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CONCLUSIONS AND SCOPE FOR FUTURE WORK

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In this chapter, the performance of the AEMAC scheme, which takes into account the time varying nature of wireless channels in a wireless sensor network and the cross layer interaction between the Physical layer, MAC layer and the Network layer, is discussed. The extensive simulations conducted have demonstrated that the behavior of wireless channels can greatly influence the network Energy Consumption. The conclusions observed and the scope for future research work is briefly illustrated below.
Conclusion and scope for future work

Wireless ad hoc networks of battery powered micro sensors are proliferating rapidly and transforming the way information is gathered, processed and communicated. These networks are envisioned to have hundreds of inexpensive sensors with sensing, data processing and communication components. They typically operate in unattended mode, communicate over short distances and use multi hop communication. Many challenges are introduced due to the limited energy, large number of sensors, unfriendly working environment and nature of unpredictable deployment of the sensor network. Energy conservation is found to be the foremost among them since it is often cost prohibitive or infeasible to replenish the energy of the sensors. This energy problem in wireless sensor networks remains one of the major barriers somehow preventing the complete exploitation of this technology. Efficient Energy Management is proved to be the key requirement for the credible design of a wireless sensor network.

The general framework for energy efficient data acquisition is based on a duty cycle approach requiring the sensor to be switched OFF during idle time. Dynamic Power Management is an effective tool in reducing the system power consumption without degrading the performance. The quality of wireless channels or the network topology can change rapidly even in a static network. Routing protocols should quickly detect these dynamics and take measures to maintain robust and efficient routing paths. This needs to be considered in the design of a wireless sensor network. Moreover a cross layer design on power aware communication, considering the time varying nature of wireless channels, is needed to optimize the energy usage. In this work, all the above mentioned ideas are incorporated. Here each sensor node judiciously accesses the wireless medium and communication activity is reduced for those sensor nodes, under poor channel conditions. Hence the time varying nature of wireless channels are taken into
account in this work, in the optimization of energy management in a wireless sensor network.

7.1 CONCLUSIONS

- For an increase in the node density, *Energy Consumption* increased for AEMAC, SMAC and ZMAC schemes, due to the increase in routing involved. AEMAC scheme exhibited the lowest *Energy Consumption*, since more nodes are brought to the sleep state, on an increase in the node density. Moreover the mandatory wake up involved in the other power saving schemes, is not used here leading to its better performance compared to the other schemes. ZMAC scheme showed the maximum *Energy Consumption*.

- For an increase in node density, *Throughput* decreased for AEMAC, SMAC and ZMAC schemes. This may be due to the more routing decisions involved on an increase in node density resulting in less fraction of the channel capacity being used for data transmission. The improved methodology of the AEMAC scheme led to its increased *Throughput*.

- On an increase in node density, *Delay* decreases for all the three schemes AEMAC, SMAC and ZMAC. This is due to the large number of nodes getting involved in routing, which results in quicker data delivery to the sink through these nodes. Later *Delay* settles to a steady value in all the three schemes. AEMAC scheme exhibited the lowest *Delay* and SMAC scheme showed the largest *Delay*.

- An increase in *Transmission Rate* provided a decrease in *Energy Consumption* for all the three schemes AEMAC, SMAC and ZMAC; since all the schemes use their power conservation methods effectively in
transmitting the large number of data packets transmitted per unit of time. Moreover the start up energy overhead also decreases on an increase in the Transmission Rate. AEMAC scheme showed the lowest Energy Consumption and ZMAC scheme showed the highest Energy Consumption. So an increase in Transmission Rate can be opted as a good method to decrease the Energy Consumption in a wireless sensor network.

- On an increase in the Transmission Rate, Throughput increases for AEMAC, SMAC and ZMAC schemes because the large amount of data which is transmitted gets serviced by the communication system. AEMAC scheme provided a very large Throughput compared to the other two schemes. Thus an increase in the Transmission Rate can be an effective method to increase the Throughput in a wireless sensor network.

- An increase in Transmission Rate initially provided a slight increase in Delay for SMAC and AEMAC schemes. AEMAC scheme provided the minimum Delay along with ZMAC scheme and SMAC scheme provided the maximum Delay. So static schemes prove to provide higher Delay in a wireless sensor network. Also the increase in Transmission Rate has very little effect on the Delay encountered by the data packets in a wireless sensor network.

- An increase in the Transmission Rate provided a better Delivery Ratio for AEMAC and ZMAC schemes. The Delivery Ratio of SMAC scheme which was initially higher than ZMAC scheme for a lower Transmission Rate, stooped to a low value on an increase in the Transmission Rate. Thus in a wireless sensor network, the better performance of the static schemes in terms of Delivery Ratio gets degraded on an increase in the Transmission Rate. Also the increase in the Transmission Rate can provide a better
Delivery Ratio in a wireless sensor network which uses effective route selection policies.

- As the node density increases, the Delivery Ratio decreases for all the three schemes AEMAC, ZMAC and SMAC. AEMAC scheme exhibits the highest Delivery Ratio compared to the other schemes.

- As the number of flows increases, Delivery Ratio increases slightly for AEMAC and ZMAC schemes. AEMAC scheme shows the maximum Delivery Ratio and ZMAC scheme provides the minimum Delivery Ratio.

- For an increase in the Transmission Rate, AEMAC scheme could receive a much higher Bandwidth compared to the SMAC scheme. In wireless sensor networks, increase in the Transmission Rate can be opted for increasing the Bandwidth in the network.

- On an increase in the Transmission Rate, Fairness increases considerably for the AEMAC scheme compared to the SMAC scheme. So to achieve better Fairness in a wireless sensor network, the increase in Transmission Rate can be selected as an optimum method.

- The Bandwidth decreases in a wireless sensor network having a higher Error Rate. But the decrease is lesser in a network which adopts channel adaptive schemes thus proving the better performance of the AEMAC scheme compared to the SMAC scheme.

- Fairness decreases in a wireless sensor network having a higher Error Rate and the SMAC scheme shows a very low Fairness compared to the AEMAC scheme. In a wireless sensor network with varying channel conditions, it is difficult to achieve Fairness. The Load Prediction algorithm
and the Threshold adjustment scheme of AEMAC scheme accounts for the increased *Fairness*, even in a network with a higher error rate.

- In a wireless sensor network, on an increase in the *Error Rate*, the *Delay* increases considerably for SMAC scheme compared to the AEMAC scheme. If proper channel adaptive schemes are used in a wireless sensor network, the *Delay* encountered by the data packets can be considerably reduced, which is proved in the superior performance exhibited by the AEMAC scheme.

- On an increase in the *Error Rate* in a wireless sensor network, the *Throughput* decreases. The AEMAC scheme provides a much higher *Throughput* compared to the SMAC scheme proving that channel adaptive protocols can be used effectively in a wireless sensor network, with varying channel conditions.

- On an increase in the *Error rate*, the *Delivery Ratio* decreases initially and then remains almost constant for both AEMAC and SMAC schemes. AEMAC scheme shows a better *Delivery Ratio* compared to the SMAC scheme at high error rates, proving that the channel adaptive techniques adopted in the AEMAC scheme can provide a better performance in a wireless sensor network, with varying channel quality.

### 7.2 Scope for future work

This work had implemented an Energy efficient Channel Adaptive MAC protocol in a wireless sensor network with static nodes. This scheme had provided improvement gains in *Energy efficiency, Throughput, Delay, Bandwidth* and *Delivery Ratio*. But the superior nature of this scheme depends on many environmental factors, such as operation scenarios, specific data types etc. Thus
more research work needs to be done in future to find the respective application scenarios for this scheme with all the related factors taken into consideration. This technique needs to be implemented in a wireless sensor network with mobile nodes, since mobility was not taken into account in this work. The effects of very large node densities need to be investigated. Multi hop routing was adopted in this work. The feasibility of using the clustering technique and data aggregation needs to be tested in the same wireless sensor network. In this work, energy problem was not tackled at the Transport layer. Means to devise this scheme from the Transport level view point needs to be explored.