Routing Schemes for Wireless Networks using Artificial Intelligence

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Abstract—With the increasing demand and penetration of wireless services, users of wireless networks now expect Quality of Service (QoS) and performance comparable to what is available from fixed networks. Providing QoS requirements like good throughput and minimum access delay are challenging tasks with regard to 802.11 WLAN protocols and Medium Access Control (MAC) functions. Wireless local area networks (WLANs) are in a period of great expansion and there is a strong need for them to support multimedia applications. Wireless networks are becoming more and more popular in recent years, ranging from digital cellular telephony up to satellite broadcasting. Different researching issues have been extensively developed: power consumption, MAC protocols, self-organizing network algorithms, data-aggregation schemes, routing protocols, QoS management, etc. Due to the constraints on data processing and power consumption, the use of artificial intelligence has been historically discarded. However, in some special scenarios the features of neural networks are appropriate to develop complex tasks such as path discovery, which has the novelty of being based on the introduction of neural networks in every sensor node to optimize the route using neural networks. This paper attempts to encourage the use of artificial intelligence techniques in wireless sensor nodes.

Keywords— Adaptive sensors, Medium access control, neural networks, Wireless networks.

I. INTRODUCTION

This recent years technological advances have made the manufacturing of small and low-cost sensors economically and technically possible. These sensors can be used to measure ambient conditions in the environment surrounding them. Typically, wireless sensor networks (WSNs) contain hundreds or thousands of those sensors nodes. Due to the sensor features (low-power consumption, low radio range, low memory, low processing capacity, and low cost), self-organizing network is the best suitable network architecture to support applications in such a scenario. Goals like efficient energy management, high reliability and availability, communication security, and robustness have become very important issues to be considered. This is one of the many reasons why we cannot neglect the study of the collision effects and the noise influence. With the advent of wireless local area networks (WLAN) the bandwidth has been increased and the prices have been have been decreased on wireless networking solutions [1]. This factor has been been made the WLAN a very popular wireless network solution. As the technology is improving, the demands of end users and their applications increasing. A wide variety of new applications are being invented daily. These applications have different demands from the underlying network protocol suite. The IEEE 802.11 standard for the WLAN is the most widely used WLAN standard today. Since it uses a shared medium, it has some inherent problems such as low medium utilization, risk of collision and problem of providing differentiation between different types of traffic. We study and evaluate the different schemes used in the wireless networks for providing the quality of service (QoS) while achieving optimized route.

II. SYSTEM DESIGN CONSIDERATIONS

We propose to explore how artificial intelligence techniques can be used to help wireless sensors capture a measurement of interest within the constraints of the sensor network. We intend to employ a novel strategy based on random forest regression and reinforcement learning for placing sensors and organizing an optimal network topology. Because the sensors’ battery power is limited and signal strength varies, algorithms for adaptive measurement and communication that optimize power usage while ensuring that events or measurements of interest are adequately captured are essential to deployments like ours. Additionally, a method that allows researchers to detect areas where additional sensors would be useful or where existing sensors were redundant, would allow the distribution of sensors to be optimized.

A. MAC Layer Protocols

Distributed Coordination Function (DCF) uses a Carrier Sense Multiple Access with Collision/ Avoidance mechanism (CSMA/CA) algorithm to immediate the access to the shared medium. Therefore, in an event of contention, acknowledgement will have higher priority data and management packets. Because DCF was originally designed for data applications, its main weakness is the lack of QoS support (absolute throughput, relative throughput, or delay support). Whenever a data is to be sent, the station senses the medium, if it is free at least a DCF inter-frame space (DIFS)
period of time the frame is transmitted. Otherwise if the medium is busy, a back-off time $B$ (measured in time slots which depends on the physical characteristics of physical layer) is chosen randomly in the interval $[0, \text{CW}]$, where the CW is the contention window.

![Inter-frame Space Relationship](image1)

Fig. 1 Inter-frame Space Relationship

After the medium has been detected idle for at least a DIFS, the back-off timer is decremented by one for each time slot the medium remain idle. When the back-off timer reached to zero, the frame is transmitted. Upon detection of collision a new back-off timer is now chosen and the back-off procedure starts over. After a successful transmission, the contention window is reset to $\text{CW}_{\text{min}}$.

Point Coordination Function (PCF) is a polling based mechanism which require the presence of a base station that act as the Access point. If PCF is supported, both PCF and DCF coexist and in this case, time is divided into two super frames as shown in the fig. 1 of super frame of IEEE 802.11 WLAN. Each super frame consists of a contention period where PCF is used. The CPF is started by a special frame (a beacon) sent by the base station. Since the beacon is sent by using the ordinary DCF access method, the base station has contended for the medium, and, therefore, the CFP may be shortened [3].

![Super-frame of IEEE 802.11](image2)

Fig. 2 Super-frame of IEEE 802.11

The AC keeps a list of mobile stations that have requested to be polled to send data. During the CFP, it sends a poll frame to the station when they are cleared to access the medium. Upon the reception of a poll frame, the station sends a data packet if it has any packet queued. To ensure that no DCF station are able to interrupt this mode of operation, the IFS between PCF data frame is shorter than usual DIFS. This space is called PCF inter-frame space (PIFS). To prevent the starvation of station that are not allowed to send during the CFP, there must always be room for at least one maximum length frame to be sent during the contention period(Fig.2).

**B. Physical Layer Protocols**

This standard specifies a 2.4GHz operating frequency with data rates of 1Mbps and 2Mbps. The initial 802.11 standard defines two forms of spread spectrum modulation: frequency hopping (FHSS) and direct sequence (DSSS).

Spread Spectrum is a modulation technique that spreads the data transmission across the entire available frequency band [2]. Spread spectrum also permits many users to share the same frequency band with Minimal interference from other users or from devices. In the original standard, there were two different types of spread spectrum transmissions defined for the Physical Layer.

**Frequency Hopping Spread Spectrum**

Frequency Hopping Spread Spectrum (FHSS) Physical layer uses frequency hopping spread spectrum to deliver 1Mbps and 2Mbps data rates in the 2.4GHz band. With FHSS, a transmitting and receiving station (with WLAN: Access Point and Network Interface Card) are synchronized to hop from channel to channel in predetermined (pseudo random) sequence. The predefined hopping sequence is only known to the transmitting and receiving station. By doing so, it is very difficult for someone to catch up the signal, because other stations don’t know on which channel the signal will be transmitted next. If one channel is jammed, the data is simply retransmitted on the next channel in the hopping sequence. Networks using 802.11 and FHSS are limited to maximum 2Mbps. Frequency-hopping spread-spectrum (FHSS) uses a narrowband carrier that changes frequency in a pattern known to both transmitter and receiver. Properly synchronized, the net effect is to maintain a single logical channel. To an unintended receiver, FHSS appears to be short-duration impulse noise.

**Direct Sequence Spread Spectrum**

DSSS the information to be transmitted is divided into small pieces. These small pieces are spread across the entire available frequency band. The pieces of information are encoded by using a redundant pattern, called a chip. This chip is only known by the transmitting and receiving device. The redundant pattern also makes it possible to recover data without retransmitting it if one or more bits are damaged. This means that the signal is less susceptible for interference. The longer the chip, the greater the probability that the original data can be recovered (of course, the more bandwidth required). Even if one or more bits in the chip are damaged during transmission, statistical techniques embedded in the radio can recover the original data without the need for retransmission.

**III. IMPLEMENTATION**

Sensor Placement
When monitoring areas of interest, it is important to distribute sensors in such a way that they capture the phenomena of interest without being redundant. In addition, sensors must be placed so that the network is capable of reporting measurements from regions of interest without prematurely exhausting the battery power of sensor or intermediate nodes. We propose to address the question of sensor redundancy by using random forests to predict a sensor’s time series based on the time series data from other sensors of the same type. If a sensor’s measurements can be accurately predicted by the other sensors, it may be judged as potentially redundant. If they are poorly predicted, another sensor may need to be placed nearby to accurately capture the spatial in homogeneity of the field being measured. In addition, sensors that are triggered to report or relay data more frequently may require the addition of other sensors or network nodes in the same region to ensure that the data can be reliably communicated without exhausting any sensor node’s battery power.

Adaptive Sensor Reporting

Real environments, however, evolve in time both in terms of the observation system and the process being measured. Learning relationships between data from various sensors “on the fly” will allow the identification of significant events or changes in the dominant regime as they occur. These events may require that additional measurements be taken to adequately capture the transitions. We propose again using random forests for this purpose, training new trees in the forest as new data come in and aging off old ones to maintain a robust but adaptive predictive model. If the ability of the random forest to predict or relate the incoming sensor measurement values suddenly falls off, the base station would then signal the sensors to increase their reporting accuracy [4].

We say reporting “accuracy” instead of reporting “rate” because we envision that the sensor nodes will report in a novel way. Instead of reporting at fixed temporal rates, the sensors will be supplied with a prescribed reporting accuracy, or “tolerance”. Recent past measurements will be used to fit a linear or quadratic “trend” to the sensed data, and if a measurement falls outside of the prescribed tolerance from the trend’s prediction, a new report will be made. That report will include not the measurement itself, but the time and the parameters of the observed trend. The base station will then be able to provide measurements and error bars for all times based on the reported trends and error tolerances, and will be able to request that a smaller tolerance be used if the situation mandates greater accuracy [8, 9].

Network Routing

Network routing will be optimized by applying reinforcement learning techniques, with network parameters being optimized periodically (e.g., nightly) based on the network’s recent performance. We envision that the network’s routing strategy will be stochastic at each node, an appropriate probability distribution over parent nodes being selected at each time step based on the sensor’s state and its knowledge of the state of the network.

Relationship Discovery

Finally, another use of random forests is in analyzing the multi-sensor, multi-scale data collected by the sensor array deployment to discover relationships that may be of scientific value. For instance, the purpose of the Niwot Ridge deployment is to determine how various environmental factors are related to carbon flux in a complex alpine ecosystem. In addition, the random forests are capable of providing lists of the most important variables to the learned relationships; these may prove helpful in determining what physical phenomena are related [5, 6, 7].

IV. Neural Networks

The necessity of connectivity among nodes introduces the routing problem. In a WSN we need a multi-hop scheme to travel from a source to a destiny. The paths the packets have to follow can be established based on a specific criterion. Possible criteria can be minimum number of hops, minimum latency, maximum data rate, minimum error rate, etc. For example, imagine that all the nodes desire to have a path to route data to the base station [11].

In this situation, the problem is solved by a technique Our approach to enhance this solution is based on the introduction of artificial intelligence techniques in the WSNs: expert systems, artificial neural networks, fuzzy logic and genetic algorithms. Although there are many authors who have proposed the introduction of different called network backbone formation. AI techniques in several applications over WSNs, only a few have considered the possibility of implementing an AI technique inside a sensor node. Due to the processing constraints, we have to consider in a sensor node, the best suited, among all these techniques, is the self organizing-map (SOM). This kind of artificial neural network is based on the self organization concept [10].”

V. Conclusion

After comparing the results obtained with every routing paradigm, we can conclude that the differences are important when there is a significant percentage of a node failure. Thus, while the average delay goes up with the number of sensors in directed diffusion and EAR, it maintains a low level of delay in SIR. The cause of this effect can be found in the fact that while directed diffusion and extensions. Techniques for placing wireless sensors to adequately capture measurements of interest and dynamically managing their reporting accuracy and network topology to capture significant events while maximizing battery life will become more important as wireless sensor networks continue to enter complex new areas of application, such as the Niwot ridge deployment described in the present paper. Previous sensor array research in this area has focused primarily on theoretical analysis independent of actual network operation and physical process evolution. We believe the artificial intelligence techniques we have described will offer insight into whole system management and process
system discovery, while paving the way for a complex sensor deployment that we hope will cast new light on the processes related to heating.

REFERENCES