An Efficient Streaming of High Bandwidth Data with Mobile Nodes in WSN

[1]Girish B.G, [2]Ajay HC, [3]Pradeep Kumar G.M, [4]Srinath GM, [5]Prof. Apoorva S

[1,2,3,4,5]Assistant Professor, Department of CSE,SJCIT

Abstract-A wireless sensor network with multimedia capabilities typically consists of data sensor nodes, which sense, for instance, sound or motion, and video sensor nodes, which capture video of events of interest. Streaming multimedia data in WSN is a challenge due to constraints such as bandwidth, energy and delay. More-over, it is not economical to have multimedia sensors integrated with static nodes in the field. In this paper, we propose the use of mobile sensor nodes, which are equipped with multimedia sensors for event monitoring. These mobile entities are capable of streaming high bandwidth data by splitting it and routing the packet to the base station using Frequency Division Multiplexer (FDM) modules. This is done with the support of multi-channel disjoint path routing aided with the static WSN deployed. The paper adopts a node disjoint multi-path routing protocol for establishing parallel paths between the sender and the receiver.

Index Terms-Multimedia Streaming, Multichannel MAC, Mobile WSN Wireless Sensor Network, Disjoint path routing, Traffic Splitting, Throughput Analysis, Multiple Channel Protocol.

I. INTRODUCTION

The field of Wireless Sensor Networks (WSNs) is receiving much attention in the networking research community and as an interdisciplinary field of interest. Wireless sensor networks (WSNs) typically consist of a large number of intelligent battery-powered sensor nodes with sensing, processing and wireless communicating capabilities. Advances in robotics and low power embedded systems have enabled multiple applications in the area of Wireless Sensor Networks (WSN). Low profile nodes used in such applications have limited capacity and are generally deployed in a remote location where they sense, collect, process and transmit data to the base station. Since sensor nodes have energy and bandwidth constraints, using them to transfer high bandwidth data poses several challenges in design and implementation.

In certain WSN applications, such as intruder detection, habitat monitoring, etc., the sensed data from the field is not enough to conclude about the nature of the event. In such cases the sensor field is directly inspected via a patrol team. If the application environments are harsh or remote, manual intervention is not viable.

At times sensor nodes capture attenuated or noisy data from the environment resulting in false alarms. In most applications, a false alarm is as bad as a missed event, as this may lead the user to ignore further alarms and as a result any event detected will go unnoticed. Most monitoring applications require a large amount of data to be evaluated from an event in the sensor field. Analyzing multimedia data like audio, video or image from the sensor field will be further useful for making any decision about the event [1] [2]. This can be done by interfacing multimedia sensors with the sensor nodes. Integrating media sensors with static nodes will add to the cost in terms of bandwidth and energy. Moreover, this solution is not economically feasible.

In this paper, we propose the use of a mobile node with multimedia sensors for sensing an event. Use of the mobile nodes to sense events have already been studied in various literature. Use of data mules to gather data from the static nodes and deliver it to the sink is proposed in [3]. Use of one or more mobile sinks to collect data from static nodes has been proposed in [4]. Mobile node based connectivity restoration is explained in [5]. The proposed approach uses multiple in-built radio modules to transmit the data to the base station via multipath disjoint routes. Experiments were conducted using TelosB and MicaZ motes to evaluate the performance. Static nodes were deployed in a grid like fashion. Data streaming was done via multiple paths from source to the base station.

II. BACKGROUND

Streaming high bandwidth data such as multimedia data in WSN is more demanding in terms of network overhead when compared with data communication from ordinary sensors such as motion, sound, light, etc. Most multimedia WSN applications use high end microprocessors for media data processing. Even though the use of these processors makes the sensor node more powerful, the computational cost for operations such as compression and coding of multimedia data is very high. From [1] it can be inferred that the cost and processing power of multimedia motes are higher when compared to TelosB and MicaZ motes. This makes them expensive as well as less energy efficient for long term deployment in the field.

Most WSN applications use Zigbee (IEEE 802.15.4) for communication. TelosB and MicaZ modules from

Crossbow uses chipcon cc2420 radio(IEEE 802.15.4) which support 16 orthogonal channels in an unlicensed band, each of which has a capacity of 250Kbps [7]. In reality, the data rate depends on the number of contending nodes, radio transceiver capabilities and the presence of other users communicating over the same band. Using multiple radio/FDM modules in a single sensor node will make it less energy efficient as most of the power will be consumed for communication.

The low data-rate of Zigbee protocol makes it challenging to stream multimedia data. Testbed results in [8] shows that in reality the data rate achieved in a multi-hop communication is much lesser than the theoretical standard due to the micro-controller performance and the bus architecture of the sensor node. Another reason includes channel interference, node orientation, environmental conditions, etc.

Since the interference range of a wireless communication is larger than the communication range [9], multi-channel based MAC offers a better throughput when compared to single channel based MAC protocols. Usually channel assignment in multichannel MAC will be done in advance (static) or dynamically where each node will be assigned a physical channel. If the assigned channel is different from its neighbor, then channel switching has to be done before transmitting data. Multi channel allocation has to be done carefully, so that motes using the same channel should not be in interference radius. The need for assigning same channel to a node after (I + d) distance is discussed in [9], where d is the safe communication distance, at which 99.9% of the packets are delivered and I is the interference range.

Transferring multimedia data via sensor nodes require a higher data rate with better packet delivery ratio. One way to achieve this is by establishing parallel multiple routes from the source to the destination. In this work, we propose the use of a mobile entity with multiple FDM modules which can commu-nicate with the base station via multiple paths. Use of multiple FDM based sensor motes are proposed in the literature [10]

[11].We also propose to use multi-channel communication as a MAC layer protocol. The advantages of using multichannel communication are increased data delivery ratio, parallel data transmission from multiple sources, reduction in propagation delay and enhanced robustness [12]. We adopt a node disjoint routing between the source node and the base station with minor modifications. Use of multi-path routing to deliver data has advantages like increased throughput, improved security, and reduction in the effective data rate in each path and hence improved energy efficiency.

The aim is to study the maximum achievable throughput with multichannel MAC, single channel MAC with CSMA enabled (as well as CSMA disabled), in order to empirically determine the maximum sustainable capacity between the source and the destination. A prototype of a mobile node was built which can navigate in the sensor field and also capable of establishing simultaneous communication via two IEEE 802.15.4 modules.

III. PROPOSED APPROACH

This paper proposes the use of mobile wireless sensor node for streaming high bandwidth data from the sensor field to the base station with the help of static nodes deployed. The paper aims to empirically determine the maximum capacity in a multi-hop communication using Zigbee protocol. Considering the cost of using multimedia sensors in static network, we propose the use of mobile nodes with high computational capabilities integrated with multimedia sensors and multiple radios. We adopt a node-disjoint multi-path routing protocol with some modification to establish parallel communication paths between the mobile node and the base station.

The proposed approach is divided into three phases accord-ing to the sequence of operations, which take place in the sensor field right from the initial deployment till the data reaches the base station. Network initialization phase (first phase) starts immediately after the node deployment. In the first phase, each static node determines its neighbor through whom it can route its data to the base station. In data sensing phase (second phase), a static node sense for an event in the sensor field. If an event is sensed, static node inform the base station via the path computed in the previous phase. Once an event is detected, base station instructs a mobile node (geographically near) to relocate to the location of the event. The third phase of the proposed approach is the media transfer phase. This is done with the help of multiple radio modules in the mobile nodes. This phase includes positioning the mobile node to capture an event, establishing multiple paths between the mobile node and the base station. Static node uses multichannel MAC protocol for transferring data to the base station.

Assumptions: In this work, we assume that the mobile nodes are capable of performing operations such as compression and coding with the sensed media data. We also assume that the base station supports multiple FDM implementations to accept the traffic coming from different path simultaneously.

A. Phase I - Network Initialization

Network initialization phase begins with route discovery, where static nodes need to find a routing path to the base station. This path is used only in the second phase to inform the base station about an event. Deployment we followed is a grid topology where nodes are separated by d distance, where d is the safe communication distance.

1) Routing: A communication path needs to be established between each deployed node and the base station. We followed the approach in [13], to establish a route from each static node to the base station. The sensor node uses this path to com-municate to the base station if any activity is detected. Also mobile node contacts its nearest static node to communicate with the base station. The base station employs reverse source path routing [14] to

communicate back. This is done with the help of source path field in the message received from the mobile node. Source path field carries the address of the intermediate nodes in the routing path. Base station use this field to communicate back to the mobile node.

2) Channel assignment: In wireless communication, the main reason for the reduction in traffic capacity is due to interfering nodes. Nodes which are communicating in the same channel create interference. One possible way to avoid interference is to use orthogonal channels for communication. The main challenge in multichannel MAC protocol is the channel assignment, where same channels should not be assigned to nodes with in the Euclidean distance I +d, where the interference range I is always greater than the safe communication distance d [9]. In our work, we assume that the interference range is 2d, so that the nodes using the same channel should be away from each other, at an Euclidean distance of 3d. Since our approach follows a centrally coordinated system [15], we adopt the method mentioned in [6] to calculate the channel for each static node which is done in Network Initialization phase. Phase I and Phase II communication are done in common channel.

B. Phase II - Data Sensing

The static nodes sense the physical parameters in the environment which are sent to the base station via the routing path established in the first phase. If the base station detects the presence of an event, it selects a mobile node, by comparing the Euclidean distance between the location of the event and the mobile nodes. The base station sends a unicast message (Mi) to the corresponding mobile node to relocate to the new position. The message is routed to the chosen mobile node with the help of source path field in the received message from the mobile node. After receiving the message Mi, the mobile node will relocate to the new position. The mobile node uses its localization module with the help of orientation sensors to navigate to the assigned destination.

1) Mobile node Architecture: Mobile nodes mentioned in this approach consists of a high power micro-controller with multiple radio modules. These mobile wireless sensor nodes are integrated with two types of sensors: i) media sensors for sensing multimedia data and ii) data sensors for sensing the physical parameters from the environment. The orientation of the mobile node can be estimated using an on-board digital compass. Each mobile node contains a localization module which helps in determining its location. In practice, a GPS module can be used for this purpose. Another way to localize a mobile node is by trilaterating its position w.r.t the static nodes deployed. Mobile nodes also consist of a driver circuit with DC motors attached and an energy source to drive them. The architecture of the mobile node is shown in the Figure 1. Proof of concept of the same was done using custom designed mobile robot named as B-bot.

C. Phase III - Media Transferring

A mobile node after reaching the assigned location will activates the media sensors. The data captured by the multimedia sensors undergoes operations such as compression and coding, before being transferred. The processed data is split into n

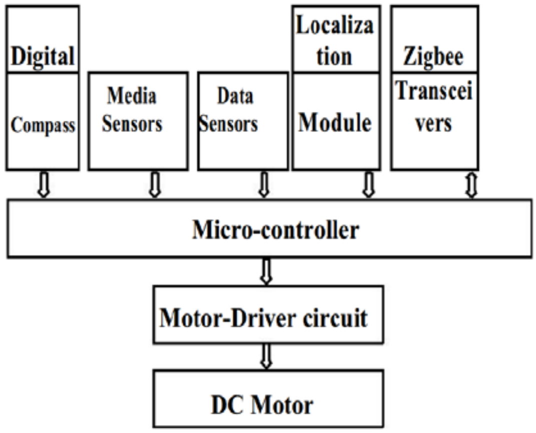

Fig. 1. Mobile node architecture

Streams, where n = min (a; p). The value of a corresponds to the number of FDM modules available in the mobile node, while p corresponds to the maximum number of disjoint paths possible between mobile node and the base station. Based on the value of n, multiple connections are established between the mobile node and the static nodes. In this paper, we also adopt a node-disjoint multi-path routing protocol to establish parallel routes and hence increase the overall data rate.

The data rate is inversely proportional to the number of hops between the source and destination. It also depends on the queuing mechanisms implemented. Many literatures propose implementing a priority based queuing model in relay nodes for streaming multimedia data [1]. Implementing such complex algorithms in a low profile mote such as TelosB or MicaZ will affect its performance. In our work, we also focus on MAC layer protocol so as to improve node to node reliability and hence by increasing the data rate. Since streaming of media data is done via static sensor nodes, the practical data rate achieved will be less than the theoretical maximum. Our experimental results show that the data rate depends on the number of hops and the MAC algorithm implemented.

1) Serial Communication: The proof of concept of the proposed model was done by connecting multiple TelosB motes into a micro controller via serial ports. Data packets were generated to send to the motes via serial ports. The motes after receiving these packets will in turn send this to the physical media. The serial communication sub-module is the TinyOS communication module which allows mote-

pc communication over serial port. In TinyOS 2.x, the serial stack structure is divided into four modules. Dispatcher handles the data packet bytes and delimiters. This module is responsible for reading as well as writing the data byte while receiving or sending a packet. Protocol unit is responsible for reading and sending all protocol control packets. Encoder/Framer converts the packet it received from protocol module into raw data byte using a serial protocol encoder/framer. The last module in the stack is raw UART, whose functionality is to configure the speed, stop byte, flushing the UART and sending/receiving bytes. Implementation details of the serial stack can be referred from [16]. Serial data packet includes 7 byte header and payload. The size of the packet payload can be set in SerialP acketInfo interface in TinyOS using the command uint8 t data Link Length.

2) Multi-path Routing: As mentioned in section III-C the number of paths that can be established between the mobile node and the base station, depends on the total number of radio modules available in the mobile node and the number of disjoint paths possible between the mobile node and the base station which is represented as n = min(a; p). For a dense network, the value of p can be represented as p = min (Mn; Dn), where Mn is the total number of neighbors to source/mobile node and Dn is the total number of neighbors to destination. We follow the approach mentioned in [17], a simple multi-path routing technique, which is not only suitable for grid topology but also for any dense random deployment. A small modification was made in the calculation of back-off time in [17]. A node will check its neighbor list to select the next hop neighbor satisfying the following three conditions: 1) Nodes close to the destination; 2) node position w.r.t source-destination line and 3) each node is distanced more than d=2 from the source-destination line. Since we are using multichannel based MAC protocol, the data loss due to interference will be less. So the constrain of choosing a node which lies more than d=2 distance from the source-destination line is not necessary. So, calculation of multiple paths is done with out considering the third constrain. Network performance not only depends on the network layer protocol but also on MAC layer protocol. Section III-C3 explains the MAC protocol we used in our approach.

3) MAC Protocol: Experiments were conducted to analyze the data rate and the reliability by comparing single channel with CSMA, multichannel with CSMA and multichannel without CSMA. Results show that the multichannel MAC with out CSMA gives a better data rate when compared to other approaches. To determine the channel capacity and reliability in a single hop communication, experiments were conducted with different packet sizes. During the media transferring phase, the static nodes in the routing path will switch to the channel assigned. When a static node communicates with its neighbor, it switches its channel corresponding to its neighboring node and then transmits the data. Once the media transfer is over, the static nodes switch back to the common channel.

IV. CONCLUSION

In this paper, we have proposed the use of mobile sensor nodes for streaming multimedia data via the static nodes de-ployed. We have used multiple FDM modules for establishing multiple connections between the mobile node and the static nodes deployed. This was done with the help of node dis-joined multi-path algorithm. Multichannel MAC protocol is used as the MAC protocol to avoid data loss due to interfer-ence. Experimental results indicate that the proposed approach is suitable for transferring high bandwidth data in a sensor network. Future scope includes testing with different types of multimedia data, handling/monitoring multiple events and adding a channel assignment scheme for a random deployment of static nodes.

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