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Critical Review of Protocol for Congestion Control in Wireless Multimedia Sensor Network

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Abstract: *Wireless sensor network has drastically increases in its applications in the industry fields. Sensor node senses physical event with scalar quantities and transform data collected into digital form. It transmit data through transmission medium like infra- red or radio wave frequency. Each sensor node store information in its internal memory and distribute information as data packets to the nearby sensor node on the network and their forward transmission to other intermediate nodes, till data packet reaches it sink node or base station. Nodes are distributed in ad hoc base manner over large region of network coverage. The challenges of multiple sensor nodes sending several data packets to sensor node results congestion of data packets in the buffer of the receiving sensor node. The techniques of applying minimal spanning tree algorithm (like prim's approach) into n x n matrix cell to serve as its routing table of the receiving sensor node, will allow data packets on arrival to a node to have available cell to occupy and stay active before being process. The issue of data degradation, loss of data packets, buffer overflow will automatically be eradicated.*

Keywords: *Wireless sensors, data packets, congestion control*

INTRODUCTION

Wireless Sensor Networks (WSNs) are an emerging technology in the area of sensory and distributed computing. A WSN consists of many, theoretically up to some thousand or even millions of sensor nodes. A sensor node is generally defined as a cheap and small piece of hardware, which consists of four main units:

- One or more sensors that detect physical phenomena. Common sensors monitor scalar values of temperature, pressure, humidity, light intensity, etc.

- The sensor is coupled with a data processing unit. The latter controls sensing, application logic and network transfer. It receives data from the sensors as well as it can filter (e.g. thresholding), compress or correlate data from a series of measurement.

The network structure, the communication process and the power management of the node a real so organized by the processing unit.

- The data's wireless transmission is provided by a communication interface. Most nodes' transfer is usually based on the IEEE 802.15.4 standard because of the low power consumption of this transfer technology and the availability of low cost radios.

• For every operational electronic system an energy source is needed. Although significant progress has been achieved in the area of energy harvesting, today's standard power supply for sensor nodes is still the battery.

Generally sensor nodes are designed to be widely spread without preconfiguration. A sink, also called a base station, is normally an embedded or a personal computer which is configured to collect, save or react according to the data. The network between the nodes and the sink is built dynamically and is considered to be self-organizing.

BACKGROUND

The excessive clustering of packets from different multimedia sensor nodes to seek access into sink node has been a problem that delay transmission rate of data, causes data or packet loss, etc. These results to lack of efficiency in the Quality of Service (QoS) in wireless multimedia sensor network (WMSN).

The delay in transmitting and receiving of data are boring and require effective management to control the congestion of packets in WMSN. The distant between the base node and the sink node should be focused and calculated to achieve minimum or shortest path to transmit and receive data.

This proposed protocol will oversee the issue of congestion in WMSN. The protocol will provide multipath minimum spanning tree algorithm to address and efficiently control congestion in WMSN. It will introduce the use of several minimum spanning trees (MST) that will be able to trace and locate the sink nodes of different packets on queue seeking to deliver data to the required sink nodes. This will eliminate the congestion in WMSN, by allowing any packet that arrive base node an available routine to deliver its data to its required destination.

PROBLEM STATEMENT

The problem of congestion of packets from multiple wireless sensors gadgets seeking access to the carrier sensor multiple access (CMSA) protocol encounters clustering in the Cluster Head, causing loss or of packets, delay in transfer and sink rate of data, increase energy usability, reduce latency and efficient throughput, among other deficiencies. The issue of congestion control in Wireless Multimedia Sensor Network (WMSN) remains the focus of this research.

AIM

To improve congestion control in Wireless Multimedia Sensor Network and support its Quality of Service (QoS), using multipath minimal spanning tree.

OBJECTIVES

1. To implement auto-incremental matrix of M × N dimensional array as the routing table.
2. To use Prim's Greedy MST algorithm to implement the shortest path of data from source node to sink nodes.
3. Data packet being transmitted or received, uses a cell in the matrix array to route data from source node to sink nodes, it remains as active until transmissions are complete before being a null cell.
4. To provide and maintain vertex-index array of edge lists.

METHODOLOGY

This study will simulate a suitable remedy to improve the congestion control bottleneck in wireless multimedia sensor network, providing routing base for all data packets being transmitted by WMSN. It models a new WMSN protocol by introducing Multipath Minimum Spanning Tree protocol to maximize congestion control efficiency in WMSN. This will use matrix algorithm as a base for the routing table, allowing each data packet transmission a delicate or particular channel to route it data from source to destination, by automatically assigning a cell as its route channel. So that, the multiple of data packets being transmitted by various WMSN will be allocated different routing channels.

LITERATURE REVIEW

2.0 Introduction

Lenin Raja , Naveen Kumar , Chandramohan (2013): "In order to enhance the network lifetime by the period of a particular mission, many routing protocols have been devised. One of these is network clustering, in which network is partitioned into small clusters and each cluster is monitored and controlled by a node, called Cluster Head (CH) and also congestion avoidance can be made. In the sensor network, sensor node can communicate with the base station directly or through the cluster head, or through other relaying nodes. In a direct communication, each node communicates directly with the base station".

2.1 **Design Requirements for WMSN Routing**

Routing governs the performance of WMSNs in terms of quality of service and energy efficiency. Routing policies accommodate multiple conflicting objectives and constraints, imposed by technologies and user requirements (Caro and Dorigo, 2012).

Real-time multimedia traffic in WMSNs raises many design challenges for routing protocols:

(i) **QoS Requirements**: WMSNs are used in different types of applications. These applications need different requirements. For example, real-time multimedia applications require strictly less end-to-end delay and jitter but high bandwidth and reliability.

Various QoS requirements are given below:

(a) **Latency:** End-to-end delay requirements can be classified into soft latency bounded systems, hard delay bounded systems, and firm delay bounded systems. In soft latency bounded systems, the system needs to maintain probabilistic delay guarantee; that is, some delay in packet delivery can be tolerated. But in hard latency bounded system, the system needs to maintain deterministic end-to-end delay, which is also denoted as deadline (Li and Kim, 2014). The entire system is said to fail, if the system is not able to provide service in the deadline guarantee period.

(b) **Reliability:** It is defined as ability to deliver the data to sink node with minimum packet loss. The unreliability of a system is due to congestion and interference. So it is also regarded as reciprocal of packet loss (Caro and Dorigo, 2012).

(c) **Bandwidth:** Multimedia traffic requires huge bandwidth. In order to fulfill bandwidth requirements and utilize the resources to its maximum available capacity, routing protocols must employ multipath, multichannel, or stream division method.

(d) **Jitter:** It is defined as the accepted variability of delay between received packets (Caro and Dorigo, 2012). If the requirement is not met, then it may result in error in audio or video data stream, glitches, and discontinuity.

(e) **Lifetime:** The lifetime of a system is an important factor for deciding the performance of system.

(ii) **Energy Efficiency** (Caro and Dorigo, 2012): Multimedia sensor nodes are battery constrained devices just like scalar sensor nodes. So energy is one of the major concerns in WMSNs too. Due to network congestion, packet interference, retransmission, and too much concentration on QoS requirements, battery of sensor nodes drains quickly.

(iii) **Hole Detection** (Di Caro and Dorigo, 2012): Real-time applications require high bandwidth and low end-to-end delay. As a result, the energy of the routes that are used repeatedly exhausts quickly. This leads to the creation of special scenarios called dynamic holes. An efficient routing protocol must facilitate balanced energy usage in the whole network.

(iv) **Traffic Classes** (Caro and Dorigo, 2012): Admission control in WMSNs must be based on QoS requirements of the requested service or application as there is a need to provide differentiated service between different applications.

Various traffic classes that are defined in (Caro and Dorigo, 2012) are as follows:

(a) **Real-Time, Loss-Tolerant Multimedia Streams:** Usually, this traffic class requires high bandwidth and strict delay bounds. This class includes audio, video stream, multilevel stream, scalar data, and their metadata.

(b) **Delay-Tolerant, Loss-Tolerant Multimedia Streams:** This class includes traffic that is intended for offline storing or processing. This traffic must be transmitted in almost real-time to avoid packet loss.

(c) **Delay-Tolerant, Loss-Intolerant, Scalar Data:** This class includes data from monitoring process and data which are intended for offline storing or processing. The bandwidth requirement is low.

(d) **Delay-Tolerant, Loss-Tolerant, Scalar Data:** This may include any scalar sensor data, non-time critical multimedia snapshot whose bandwidth requirement is low.

(e) **Real-Time, Loss-Tolerant Scalar Data:** This class includes data from monitoring process or loss-tolerant snapshot multimedia. Bandwidth demand is moderate to low.

(f) **Real-Time, Loss-Intolerant Scalar Data:** This class includes data from time critical monitoring process and bandwidth requirement is moderate to low.

2.2 WMSN Routing Techniques

There are many ways to classify routing protocols depending on different parameters. The classes and subclasses are not mutually exclusive as many protocols belong to more than one class or subclass. According to current research trend, categorization of routing protocols is based on number and type of QoS constraints . Hence, QoS based routing protocols are mainly divided into latency constrained and multiconstrained routing protocols (Ehsan and Hamdaoui, 2012)

Again, based on deadline delays, latency constrained routing protocols are further classified into protocols providing hard-real-time (HRT), soft-real-time (SRT), and firm-real-time (FRT) QoS guarantees (Li and Kim, 2012). Another category called "swarm intelligence (SI) based" routing protocol is included in classification. Finally, based on the network structure, routing protocols are further classified into flat routing, hierarchical routing, and location based routing.

2.2.1 QoS Based Routing

In order to guarantee qualitative or quantitative performance parameters, the notion of QoS has been proposed by (Chen and Nahrstedt, 2008). QoS requirement for WMSNs is a set of constraints like reliability, latency, bandwidth, and jitter. Based on number and type of constraints, QoS based routing protocols are classified into latency constrained and multiconstrained routing protocols.

2.2.2 Latency Based Constrained Routing: In HRT based systems, if packets arrive after the predefined delay deadline, then this is considered as a system failure (Li and Kim, 2012). But due to lossy links and error-prone medium, it is almost impossible to guarantee HRT in WMSNs. In SRT based systems, some packet missing the delay deadline is tolerable, but a probabilistic delay guarantee is required in order to prevent the system from crashing. There are various protocols that can provide required delay deadline guarantees and deliver the data packets in SRT. In FRT based systems, -firm concept is introduced, which demands at least out of any consecutive messages must deliver before their delay deadline; otherwise, it is considered as a system failure. Therefore, it is necessary to implement priority based scheduling of stream packets.

2.3 Recent work focus to implement cross layer solutions to improve routing.

(1) **HRT Based Protocols:** The paper by (Zhou and Wang, 2010) proposed delay-constrained routing protocol. The main goal of the protocol is to provide hard real-time delay guarantees and minimize the energy consumption within WMSNs. The proposed algorithm uses global link-state routing algorithm, which needs complete knowledge of network topology in order to compute best possible paths. Global link-state routing algorithms can provide hard real-time delay guarantees. The proposed algorithm is divided into three parts. The first part removes the node with less residual energy from the graph, in order to avoid hole problem. The second part uses Dijkstra algorithm in order to find energy efficient routes. Then, the third part ensures that all the paths meet delay upper bound. If a path does not meet delay constraints, then a new path is computed using Dijkstra algorithm and delay as a performance metric.

Key features are as follows:

(i) It uses a global state routing algorithm.

(ii) It focuses on energy efficiency and QoS.

(iii) It computes delay-constrained least energy consumption tree using the Dijkstra algorithm. The proposed protocol guarantees hard-real-time delay bounds. However, the state information exchanged between nodes consumes a huge amount of memory and bandwidth. It is difficult to store and maintain state information in large WMSNs. Therefore, it is only suitable for small WMSNs.

(2) **SRT Based Protocols:** Sequential assignment routing (SAR) by (Sohrabi, Gao, Ailawadhi, and Pottieconsiders, 2011) both QoS and energy efficiency in route selection process. SAR assigns a priority level to each packet. The main objective of SAR algorithm is to minimize the average weighted QoS metric throughout the lifetime of the network. Weighted QoS metric is computed as the product of additive QoS metric and weight coefficient associated with a priority level. SAR algorithm elects special node called the central node (CN) to perform more sophisticated information processing. It uses Single Winner Election (SWE) algorithm and spanning tree (ST) algorithm. ST algorithm computes a minimum hop spanning tree rooted at CN. Failure recovery in SAR uses a handshaking procedure which enforces table consistency among neighbors. If there is a path failure, then a recomputation procedure is triggered automatically. SNR uses two cooperative signal processing techniques: noncoherent and coherent. Extensive simulation done in (Sohrabi, et al, 2011) shows that SAR has better performance than the minimum metric algorithm.

Key features are as follows:

(i) It is a table driven routing protocol.

(ii) It is both a QoS based and an energy efficient protocol.

(iii) It is a multipath and fault-tolerant routing protocol. The major drawback of SAR is that it is a table driven protocol and hence it is nonscalable. If the number of nodes increases, then the overhead of maintaining the routing table and status information increases drastically.

(3) **Real-Time Communication Architecture for Large-Scale WSN (RAP)** (Lu, Blum, Abdelzaher, Stankovic, and He, 2012) is a priority based, localized routing protocol, which provides soft-real-time delay bounds. RAP introduced a novel packet scheduling policy, Velocity Monotonic Scheduling (VMS). VMS schedules packets according to their requested velocity. VMS improves deadline miss ratio by giving priority to packets based on requested velocity. VMS is capable of reducing deadline miss ratio by as much as 72.1%. RAP assumes that each node knows its own location, making it location dependent protocol. The combination of VMS and geographic forwarding (GF) makes RAP more scalable and more suitable for multimedia traffic. RAP supports both query oriented and event oriented services.

Key features are as follows:

(i) It is a location dependent routing protocol, which implements both VMS and GF.
(ii) It provides soft-real-time delay bound guarantees.
(iii) It provides both query and event based service APIs.
(iv) It is a scalable protocol for multimedia applications. There is no need to maintain neighbor database and hence the routing overhead is very little as compared to other classical routing algorithms. RAP uses GF, which can deplete the bandwidth quickly. Also, it does not consider hop-count as routing metric and there is no direct metric to show energy conservation.

(4) **Stateless Protocol for Real-Time Communication (SPEED)**
He, Stankovic, Lu, and Abdelzaher (2013) is a stateless, localized, soft-real-time delay bounded protocol, which requires minimum MAC layer support for QoS based routing.

Stateless Nondeterministic Geographic Forwarding (SNGF) method is used for routing in SPEED. SNGF maintains desired delivery speed and traffic balance, to reduce the network congestion. MAC layer adaptation of SNGF drops packets in case of congestion. If congestion remains for a long time, then traffic is redirected to a less congested area.

SNGF uses four modules:

(a) Beacon Exchange: SNGF uses two extra beacons. One beacon is for delay estimation and the other is for back pressure.
(b) Delay Estimation: Round trip single hop delay for each packet is calculated at the sender’s site after receiving ACK.

(c) Neighborhood Feedback Loop (NFL): NFL maintains system performance by maintaining single hop relay speed above a fixed value.
(d) Back Pressure Rerouting. This module is used to reduce congestion in the network.

Key features are as follows:

(i) It is an energy efficient and localized routing protocol.
(ii) It handles congestion and provides soft-real-time delay bounds.
(iii) It avoids the void problem.
(iv) It also supports load balancing.

2.4 Routing Protocols

Initially, hierarchical protocols were proposed for routing in wired networks (Yang, 2014): However, they are also suitable for WMSNs. In hierarchical routing protocols, the entire network is divided into different levels. Nodes at different levels have different responsibilities. Generally, the protocol consists of two routing layers only, and data flows from a low level layer to a higher level layer. The nodes with the higher capabilities and responsibilities are known as CHs. Each CH can directly communicate with the BS. The rest of the nodes are called child nodes or cluster members, which associate with CHs to form clusters. Child nodes can only communicate with their CH.

The advantages of these protocols over flat routing protocols are as follows: they are more scalable, energy efficient, and reliable. Overall performance of protocol depends on the process of formation of clusters. Energy efficient and perceived QoS aware video routing (PEMuR) (Kandris, Tsagkaropoulos, Politis, Tzes, and Kotsopoulos, 2011) is a novel energy-aware hierarchical routing protocol for WMSNs, which uses intelligent video packet scheduling scheme and predicts the video distortion. It is based on scalable power efficient routing (SHPER) protocol (Kandris, Tsioumas, Tzes, Nikolakopoulos, and Vergados, 2009). CHs are further categorized into upper level CHs and lower level CHs. Upper level CHs are near BS and can transmit data directly to the BS. Whereas lower level CHs are far from the BS, distant nodes route their messages to the BS by multihop routing.

PEMuR is divided into two phases: (1) initialization phase and (2) steady state phase. The initialization phase starts with the creation of TDMA schedules for all nodes to advertise themselves and calculate relative distances between them. Random numbers of upper and lower CHs are elected by the BS. Non-CH nodes associate with CH having maximum signal strength. In steady state phase, BS elects a node with maximum residual energy in each cluster as CH. In case of nonavailability of sufficient bandwidth, each sensor node drops video packets to reduce the retransmission rate. The packets to be dropped are chosen wisely in order to minimize overall video distortion using video distortion model. The video distortion is measured in terms of Mean Square Error (MSE). The model also takes into account the random behavior of wireless medium; hence, it can predict video distortion accurately.

Key features are as follows:

(i) It is an energy-aware hierarchical routing protocol.
(ii) It uses an intelligent video scheduling scheme.
(i) It is based on SHPER protocol.
(ii) It intelligently handles low bandwidth situation.

PEMuR ensures that minimum power is consumed and required QoS is maintained for the transmission of video streams. Also, it can maintain a high level of perceived video quality (PSNR) for uniform and nonuniform energy distributions. But PEMuR is fully dependent on BSs for carrying out the routing process; hence, it is not fully distributed. Energy efficiency QoS assurance routing (EEQAR) (Lin, Rodrigues, Ge, Xiong, and Liang, 2011) protocol is a hierarchical routing protocol, which implements cellular topology to form clusters. EEQAR uses a QoS trust estimation model, which is based on social network analysis. On a social network, the relationship between two individuals is determined by the trust relationship between them. The concept of social network analysis is used by EEQAR in order to ensure energy efficiency and determine trust relationship. For building trust relationships, distributed metrics are introduced in EEQAR. Direct behavior monitoring and indirect information gathering are used in order to calculate trust value. Trust value is calculated by calculating various other factors like transmission delay, frame rate, image quality, and audio quality. On the basis of the geographical position of agents and multimedia sensor nodes, the cellular topology is formed. Agent nodes are always deployed in the center of the hexagon. Agents send advertisement messages with their ID, after deployment. Multimedia nodes join agent node with maximum signal strength. If multimedia nodes have no task, then they can go into sleeping mode. But agent nodes must remain awake. Each node maintains optimization factor table, which stores trust value, energy level, and correlation for each neighbor. The correlation factor estimates correlation between two nodes, which directly affects the fusion process. Each node finds a next forwarding node using optimization factor table. EEQAR operation is divided into various rounds. Where each round is divided into three phases: cluster building, routing probe, and steady state. Cellular clusters are formed in cluster building phase. Intracluster and intercluster routes are built in routing probe phase. Data is collected in steady phase.

Key features are as follows:

(i) It is an energy efficient hierarchical routing protocol.
(ii) It uses “data fusion” process in order to reduce unnecessary data transmission.
(iii) It uses trust analysis to fulfill application specific QoS requirement.
(iv) It uses TDMA at MAC layer to make efficient use of energy resources.

EEQAR efficiently improves performance by decreasing delay and energy utilization. But trust relationship is slowly varying and it is not error-free. Direct monitoring increases the energy consumption rate.

2.6 Multipath Routing Protocol in WSN

Mohammed and Maryam (2013) elaborate the following affirmation below:

The multipath routing technique which has demonstrated its efficiency to improve wireless sensor performance is efficiently used to find alternate paths between sources and sink. This approach is considered as one of the existing solutions to cope with the limitations of routing. In this section, the benefits and elements of multipath routing will be explained.

2.6.1. Benefits of Multipath Routing

Here, the researcher describes how these benefits are achieved.

- ❖ Reliability and Fault-Tolerance: The original idea behind using multipath routing approach in WSN was to provide path resilience (against node or link failures) and reliable data transmission. In the fault tolerance domain, whenever a sensor node cannot forward its data packets towards the sink, it can benefit from the availability of alternative paths to salvage its data packets from node or link failures.
- ❖ Load Balancing: As traffic distribution is not equal in all links in the network, spreading the traffic along multiple routes can alleviate congestion in some links and bottlenecks.
- ❖ QoS Improvement: QoS support in terms of network throughput, end-to-end latency and data delivery ratio is an important objective in designing multipath routing protocols for different types of networks.
- ❖ Reduced Delay: The delay is minimized in multipath routing because backup routes are identified during route discovery.
- ❖ Bandwidth Aggregation: Splitting data to the same destination into multiple streams while everyone is routed through a different path, the effective bandwidth can be aggregated. This strategy is particularly beneficial when a node has multiple low bandwidth links but it requires a bandwidth that is greater than the one which an individual link can provide.

2.6.2. Elements of a Multipath Routing Protocol

Three elements of multipath routing include path discovery, traffic distribution, and path maintenance which are explained below.

1. Path Discovery

Since data transmission in wireless sensor networks is commonly performed through multi-hop data forwarding techniques, the main task of the route discovery process is to determine a set of intermediate nodes that should be selected to construct several paths from the source nodes towards the sink node.

- ❖ Disjoint Multipath Routing: In sensor-disjoint path routing, the primary path is available whereas the alternate paths are less desirable as they have longer latency. The disjoint makes those alternate paths independent of the primary path. Thus, if a failure occurs on the primary path, it remains local and does not affect any of those alternate paths.

- ❖ Braided Multipath Routing: To construct the braided multipath, first the primary path is computed. Then, for each node on the primary path, the best path is computed while it does not include that node. Those best alternate paths are not necessarily disjoint from the primary path and are called idealized braided multi-paths.

2. Traffic Distribution

In spite of path discovery of multiple paths issue, another important issue that is discussed here is traffic distribution Multipath routing algorithms that optimally split traffic into a given set of paths investigated in the context of flow control .It is worth noting that the selection of the routing paths is another major design consideration that has a drastic effect on the resulting performance.

- ❖ Number of Paths: A protocol can use a single path and keep the rest as backups, or it can utilize multiple paths in a round-robin fashion, with only one path sending at a time.
- ❖ Allocation Granularity: The traffic allocation strategy that is used deals with how the data is distributed amongst the paths. The choice of allocation granularity, which is important in traffic allocation, specifies the smallest unit of information allocated to each path.

3. Path Maintenance

In multipath routing, the process of route discovery can be done when one of the routes fails or it may occur after all of the routes fail. Waiting for all routes to fail before performing a route discovery would result in a delay before new routes are available. It should be noted that initiating the process of route discovery can make high overheads whenever one of the routes fails.

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