An Effective Congestion Control Approach through Route Delay Estimation using Packet Loss in Wireless Sensor Network

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Abstract: In wireless sensor networks, congestion control and efficient routing are in much needed due to the increase in the usage of sensor devices in the diverse applications. Even in the randomness in the mobility of the devices creates dynamic topology which causes delay or packet loss in routing. The occurrence of congestion mostly due to the high volume of traffic inflow and low outflow of the data rate. This change in transmission rate results in routing delays and reduced throughput. The rate control is the major concern in applications performing regular streaming, particularly in wireless networks. This paper aims to propose an efficient Congestion Control approach through Route Delay Estimation (CC-RDE) using packet loss to control data rate for effective to minimize the packet loss during congestion. The CC-RDE mechanism will present an illustration for Delay Recognition (DR) and a method for Routing Delay Estimation (RDE) to improve the throughput and reduce the routing delay. The experiment evaluation is performed over a reactive routing protocol to improvise the throughput and reduce delay and energy consumption in comparison with other protocols

Index Terms: **Wireless sensor network, Congestion control, Route Delay estimation**

I. INTRODUCTION

A dedicated wireless sensor network (WSN) is a set of independent mobile nodes that connect using multi-hop wireless links with or without infrastructure. It has unique features including to construct dynamic network topology over a multi-hop connection in limited bandwidth and power resources. These constraints in the resources raise various problems to serve the required QoS [1]. In such congestion and delay are the two major concerns [2], [3], [4], [5]. The high intensive inflow of data results in a larger volume of data loss, longer delay, and degradation in QoS. Congestion controls mechanisms [6], [7], [8] are an effective method to mitigate this problem, but the resource constraint limitation effects such existing method performance.

The congestion in the node is caused mainly by the "buffer overflow", "link interference", or "collisions", and the most generally a TCP / IP protocol being utilized for such communications.

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However, it follows a strict hierarchical structure of the "OSI model" and has some limitations in each layer. Each fixed task layer is assigned to control the connection. Although it can occur when the data rate exceeds the data reception rate, it is important to regulate the data rate used by each source to avoid overloading the network as multiple sources compete on the link bandwidth. Lost packets often result in retransmissions and excessive amounts of packets cause network bottlenecks to reach more packets of control to congested networks [9]. The researchers focus on preventing congestion because congestion causes significant data losses in terms of their throughput and energy consumption.

Traditional TCP congestion control methods have end-to-end control capabilities for data rate and coordination [8], [10]. A congestion window is typically set to a value of 1 when the TCP connection starts. The bandwidth available for the connection can be greater than the "Maximum Segment Size (MSS)" for each RTT. The TCP source continues to increase the baud rate exponentially until a loss event occurs. After any loss notification from the destination, the transmission node implements the flow control mechanism. The main effects of congestion are delayed routing and packet loss (PL) [6], [11], [12]. For high traffic speeds, it is important to have a solution to estimate the congestion. In the end-to-end congestion control approach, the network layer does not provide clear support for the transport layer. It was mostly noted that the congestion in the network with the end system's reliance mostly on its different network behavior related to the delayed packet arrival or packet losses.

The widely used transport protocol is TCP [7], [13] and is not suitable for WSN streaming applications. The problem of PL in WSN mostly cause due to "link or path errors", which is a particular nature of the wireless network. This is due to the fact that TCP deduces missing packets as a motion for network congestion that does not always comply with the wireless network. In this paper, an efficient Congestion Control approach through Route Delay Estimation (CC-RDE) using packet loss monitoring suggest a solution to overcome the problem of the TCP congestion control mechanism.

The CC-RDE objective is to efficiently control the data rate of the application to minimize packet loss through regular monitoring process to recognize the delay, and implementing a method for

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Routing Delay Estimation (RDE) algorithm for the enhancement of the congestion control performances in high traffic conditions.

The following paper is organized into four sections. The section-2 of the paper present the related works, section-3 illustrates the proposed Congestion Control approach through Route Delay Estimation (CC-RDE), section-4 presents the experiment evaluation and result in analysis, and the section-5 present the final conclusion of the paper.

II. RELATED WORK

Due to the increase in the number of wireless media and usage of mobile devices in the field of multimedia and other sensitive applications have become a popular means of communication [14], [15]. Many studies [9], [16], [17], [18] have shown that sensor-based applications respond more slowly to due to the loss of packets during streaming and better data flow design and CONG-CTRL mechanisms can be able to achieve smooth and better throughput. Many of the proposed network models have changed with the advent of new multimedia uses. In addition, wireless networks are being a part of advanced mobile devices and streaming applications services that are becoming more widespread. However, in comparison to WSN, a regular transmitting applications experience some problems because of the inherent characteristics of an open environment of the wireless network.

Since, the WSN has the scarcity towards its resources and the variety of networks topology, the CONG-CTRL mechanism for this area must be designed according to its required features. In the preliminary works, the regular streaming was performed through the UDP mechanism [18], but it is a variable protocol and incapable to possess any CC method. Because of this nature of UDP, it is suitable for communication to multimedia applications at a fixed data rate. Because CC mechanisms cannot be organized, multimedia streams that are not replicated by UDP will unfairly utilize the TCP streams for the communication, which has a serious streaming issue in WSN and reduce network performance.

The widely applied rate control technology in wired networks is " equation-based rate control " term as "TCP Friendly Rate Control (TFRC)" [19], [20], [21]. There are three key benefits of rate control through TFRC. First, there is no reason for network instability, congestion failure can be avoided. Second, the flow of TCP, the main source of network traffic, is fair. Third, TFRC rate fluctuations are lower than TCP, where they create them appropriately for streaming applications that require continuous data superiority. The main assumption for "TCP" and "TFRC" is that PL which is an indicator of congestion. However, PL on the wireless network violation of this assumption, which can be caused by actual link errors. It cannot distinguish between TFRC or TCP between PL because of buffer overflow and actual link failure, so bandwidth does not take full advantage. Therefore, data flow rate control and CONG-CTRL over wireless networks is a current open concern in WSN.

A. Nicolaou et al. [1] assess the concept of using mobile nodes in the network to reduce congestion in WSNs. It provides a mechanism with two forms, which begin when the algorithms fail to control the current congestion. The mechanism uses the mobile nodes either to create separate routes for the mobile nodes and to direct excess traffic directly to the destination terms a "Direct MobileCC", or to place a moving node in such a position to create an alternative path by bridging two separate areas in the network, and repeat the process if necessary term as "Dynamic MobileCC" . By doing so, "Direct MobileCC" demonstrates that it is best to an average of the source of delay and lower packets loss, and at the assess of mobile nodes utilized approximately twice the energy resources compared to "Dynamic MobileCC".

In the past, several comprehensive measures [22], [23], [24], [25] have been proposed to predict congestion to reduce packet losses. M. Coudron et al. [11] predicts one-way delay increases and explains the signal of an error in the radio link. Unidirectional delay is associated with congestion because it increases evenly when congestion occurs due to increased temporary delay, otherwise, it will remain constant. Similarly, D. Barman et al. [26] recommends a "loss differentiation approach", assuming that the "round-trip time" variation is high when congestion occurs.

S. Cen et al. [10] provides an "end-to-end CC approach" that facilitates wireless transmission. Package arrival time and unidirectional delay are combined to distinguish PL due to congestion and link failure. There are two important observations in the approach. First, when there is congestion, delaying the comparative comparison method enhances monotony. Second, the time of arrival is expected to increase in the case of PL due to a fault in the radio link. Therefore, these two information is able to help distinguish between congestion and wireless errors. On the other hand, the high wireless error rate can reduce wireless bandwidth. J. Wu et al. [17] recommends using a related method to render a data stream concert in the presence of wireless faults, assuming that wireless links bottlenecks.

Other existing techniques [6], [7], [10], [18], [22] which define congestion using endpoint statistics are able to combine with TFRC to control the data rate [19]. Congestion detection schemes used to determine whether PL is being monitored as a result of congestion, TFRC is only a PL due to congestion which regulating the flow rate. One of the shortcomings of the "end-to-end statistical approach" is that the design of congestion-based congestion detection is not adequate enough to impose information across layers or modify the layer of transport.

Current research in this area has identified the development of TCP-CC because TCP resubmission is either magnificence or ineffective for real-time streaming media applications. However, research [20] has shown that the TCP friendly method can support smooth TCP throughput in mobile wireless networks, but it would yield less throughput than difficult TCP streams. In WSN the CC is also based on the characteristics of the application being utilized for the transmission.

The congestion handling protocol was being proposed using the traffic awareness and dynamic routing algorithm as "TADR" [27]. The main idea of the proposal is to describe an expected record in the field that includes a "Depth field (DF)" and a "Buffer Length field". The DF supports the default path strength of characters, which routes packets seamlessly to the destination using the shortest route. It helps to determine the pass fields and buffer size for each individual node, and if the congestion is specified, it resends the same packet in a different path, with less congestion or idle selection in the adjacent node. However, this process has two disadvantages because: (1) always sets the shortest path to reach the target first, regardless of the state of contract congestion in the specified path, (2) redirects multiple paths without any expectation. data. Traffic congestion causes delays and PL. It has been observed that most current proposals prefer the shortest way to transfer data, but at the same time, it can be very crowded. Therefore, it is necessary to ensure that delays and packet loss are handled efficiently before routing data in the path.

Based on the above observation, we improve this mechanism by selecting the "dynamic Intermediate node" to reduce congestion efficiently according to the specified route, by designing a "Routing Delay Estimation (RDE)" based on the "Delay Recognition (DR)" mechanism for the data rate and congestion control in WSN.

III. ROUTING DELAY ESTIMATION (RDE) APPROACH

A. Problem outline

In addition, when a congestion event occurs, TCP will perform a conservative response and reduce the connection rate by half. This dramatic change in communication rate can reduce the implementation of these streaming applications. Therefore, the continuation of CC in each failure will lead to the implementation of unbearable execution, although TCP controls the "overall way" congestion. Traditionally interacts with PL because it is unable to get an accurate message about the state of network congestion. Also, TCP is unable to allow for a rapid improvement in productivity. A maximum of one package can be added to "RTT" which is not suitable for broadcasting applications. Stream applications frequently include more to maintain a uniform rate. In addition, the TCP retransmission proposal may be avoided because of the loss of streaming applications.

End-to-end methodology for CC [10] incomplete in the knowledge of network congestion. In this way, the host contends with the router as a "black box" and is unable to determine the specified network congestion. In addition, an important feature of multimedia streaming applications is to maintain a more stable data transfer rate. In WSNs, problems become more important because of wireless network attributes such as navigation, link errors, media conflicts, and routing failure. Therefore, you must select the actual congestion and respond accordingly. If the network becomes congested, the router must respond to this situation because it must delete the packet.

As a result of WSNs exclusive features, TCP cannot maintain a unified data rate which is a prerequisite for the application flow. TCP uses a traditional end-to-end mechanism to control network congestion. This paper, solve this problem by controlling the data rate and congestion by estimating the Routing Delay based on the PL estimate and confirming the explicit delay of the intermediate node.

B. Packet Loss (PL) Monitoring in WSN

The congestion causes a lot of PL on the network. As previously discussed, congestion in WSN is not the only reason for PL. But its special characteristics such as node mobility, routing failure, and media competition play a key role in this loss. However, TCP, which is an end-to-end protocol, cannot distinguish the loss from congestion, and therefore many errors is occurs.

Network congestion may not be detected, or on the contrary, congestion may be limited while the network is not crowded at all. Through comprehensive assessments, the possibility of not detecting congestion, if not extreme. While the crowded situation indicates that RTT or interval enhances. However, by calculating a certain value, the possibility of recognizing the congested congestion in the overcrowded WSN is considered extremely severe due to end-to-end monitoring. Because TCP does not have information about the nature of the failure that occurs in an argument node, it is constantly associated with CC with all these missing applications, because recognizing errors can make things substandard.

This unexpected behavior leads to a severe data rate degradation, which is simply undesirable. When streaming through WSN, TCP is not able to maintain a uniform data transfer rate due to CC mechanisms. Therefore, monitoring the variety of PL is very important here.

C. Routing Delay Estimation (RDE) Mechanism

The Routing Delay Estimation (RDE) mechanism controls the transmission rate based on Delay Recognition (DR) process for the intermediate node, which specifies PL type and together contains a message about network congestion and data rate. The argument node provides a catch-up message for the sender across the destination. The following sections describe the congestion detection process.

The DR process tries to control congestion in the flow of media applications by sending an explicit message about congestion. The CC system supports an acknowledgment to conFig an argument node. The argument node uses the length of the current buffer to send the modified information to the optional fact in the IP header of the packet. Each node in the path from the source to the destination displays the data rate as it passes through the IP header of the transmit data packet. After receiving the message from the intermediate node, the receiving side sends a modified message to the source side as "DR_{Msg}"

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notification packet. The source uses these comments to adjust them using the current data rate.

C.a Determining the Packet Loss

Since TCP unambiguously performs CC in every loss that occurs in the network without knowing the type of packet loss, this seriously negates network productivity.

To demonstrate this difficulty, it uses a delay routing parameter as a "delay". Each intermediate node will conFig the "RD_{elay}" variable in each transient to 1, if the percentage of buffer length "B_{len}", from the completed receiving node to the pre-conFigd congestion threshold value as "T_c", is conFigd to "0.9" to control the rate. In the case of packet transient, if B_{len} is less than the conFigd T_c , the R_{Delay} value is set to 0. After receiving the designed packet, the destination changes this variable next to the previous message to a newly created package and moves the packet to the source.

When it receives a DR message, the source node stores a copy of "R_{Delay}" to a variable known as "RD_{prv}". If the retransmission expires, the loss caused by the source node is activated. It first tries to identify the cause after the loss before the transmission rate is lowered. This activity is performed by examining the "RD_{prv}" value. High congestion is indicated if both "RD_{prv}" and "R_{Delay}" values are 1, which means that the node buffer is filled with 90%. On determining the congestion through the assignment of "RD_{prv} " value as 1, the source node slows down the data transmission to reduce the PL. If the assignment of "RD_{prv}" value as 0, then the process of data transmission will continue in a normal rate, and if any PL happens in this period might due to some other cause instead of congestion. This clears the determination of packet loss is because of congestion and another network issue for the source node.

In Fig.1 illustrate the data flow path in a solid line from source S to destination node D, supported by node "1,2,4 and 5". To find out the explicit congestion in each node, the "B_{len}" value is identified and compared it with the "T_c " conFigd congestion value and update the data packet header "R_{Delay}" variable.

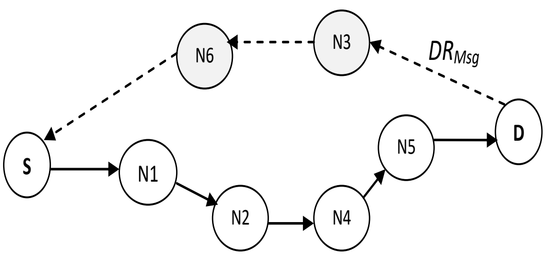

Fig 1: An illustration for the DR_{Msg} transmission Flow

On the completion of data packet transmission through the intermediate nodes, the destination node explicitly sends the DR_{Msg} to source in a shorter length route to evaluate the "R_{Delay}" and takes the advantage of the more controlled over the data transfer rate. The practical activities of these three nodes are described below to address congestion and packet loss as shown in Fig.2.

The DR messaging mechanism between these nodes supports packet transmission control and will reduce PL in case of network congestion. This control methodology will be able to achieve better throughput and reduce delay and PL compared to traditional TCP based CONG-CTRL approach.

C.b Routing Congestion Control Mechanism Using DR

The DR_{Msg} based congestion control mechanism supports improved unified packet transport through effective rate control, mostly in the regular flow application. The proposed method explicitly controls the packet rate by specifying "B_{len} " for each intermediate contract in the path to the destination. In each data packet that is received by the destination, it sends a "DR_{Msg}" message with a B_{len} update of the present situation as shown in Fig.3.

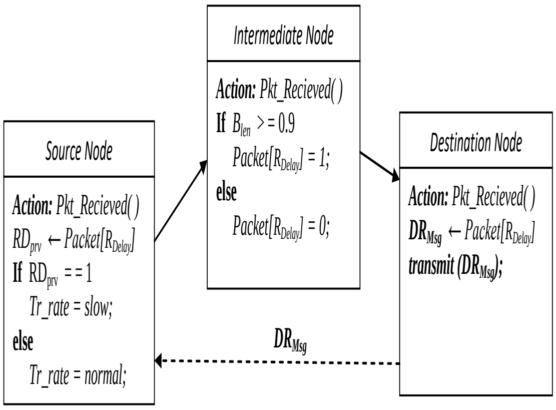

Fig 2: Functionality of each Nodes DR estimation during routing

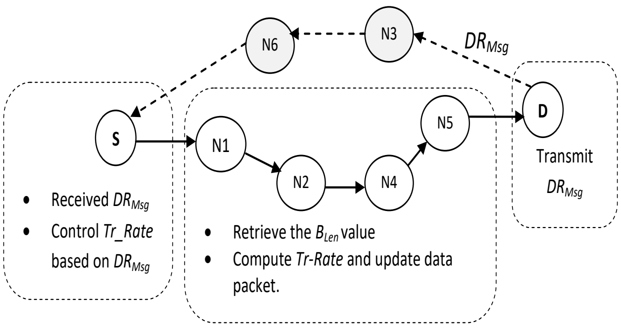

Fig 3: Congestion Control through RDE mechanism

The function of the intermediate nodes is most important the three nodes in this process. It computes and informs the congestion point through its forwarding path rather than background feedback such as TCP. This enhance the reduction of the losing a message due to a link failure or congestion, whereas if the path is redirected to the destination and the message with the delay information routed through an alternate route, it makes access to the congestion state more complete and also provides a clear congestion status at each node in the route. The computation of current DR value as "DR_{Cur}" at each individual

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intermediate node is performed by using the Eq. 1 and 2.

$$B_{Avail} = 1/ B_{len} \quad (1)$$

$$DR_{Cur} = (\beta * RD_{prv}) + ((1 - \beta) * B_{Avail}) \quad (2)$$

where, "B_{Avail}" is the current available buffer at the node, here if "$B_{Avail} = 1$" then buffer is ~100% available, and if "$B_{Avail} = 0.1$" then least availability, "β" is a normalizing factor for additional delay being assigned to a constant value as, "$\beta = 0.2$", and the "RD_{prv}" is the previous updated delay value.

According to these two Eq.1 and 2, the computed "DR_{Cur}" is applied for the routing by the source. In such case if the "DR_{Cur}" value is between 0 and 0.6 then *"Tr-rate"* is assigned to "slow", and if > 0.6 then it is assigned to "normal".

IV. EXPERIMENT ANALYSIS & RESULTS

A. Simulation Configuration and Measure

The topology model is designed on a 1000 x 1000 meter simulation space having a distribution of 50 nodes in a simulator. The number of 15 source-destination pairs is conFigd to perform data transfer simultaneously. Each data packet size is conFigd to 512 bytes and has an additional selection field to conFig for the "DR_{Msg}" value. The evaluation of the congestion and packet loss is performed by varying the source traffic rate from 100 to 500 pkts/sec, and compare the outcome with the "TADR" [27] and "Dynamic-MobileCC" [2] to evaluate the improvisation of the proposal through measuring the "average throughput", "delay" and "energy consumption".

B. Result Analysis

The following section presents the outcome of simulation at different data rate transmission in comparison results between the TADR, Dynamic-MobileCC, and CC-RDE.

Throughput Analysis: Fig. 4 shows the throughput comparison between "TADR, Dynamic-MobileCC, and CC-RDE". The CC-RDE shows an improvisation over "TADR" and "Dynamic-MobileCC" as compared to throughput due to efficient congestion handling and maintaining a smooth data flow rate. If the data transfer rate increases significantly initially to achieve more than 90% of the throughput but once it reaches the maximum buffer or packet loss occurs, it reduces the transfer rate to maintain smooth flow which reduces throughput while increasing data transmission rate. The proposed CC-RDE manages the flow of data efficiently to achieve more than 10% higher throughput compared to others in case of high traffic.

Delay Analysis: Fig. 5 shows the transmission delay comparison between "TADR, Dynamic-MobileCC, and CC-RDE". The increase in the data transmission rate offered increases traffic congestion. Each protocol initially increases the transmission rate to maintain the flow of traffic, but because of resource reduction and congestion occur the increase in RTT and also the high number of packets at the same time. As CC-RDE increases congestion by maintaining the DR estimate and setting the transmission time, reducing packet drop and also reducing transmission delay in compared with other protocol.

Energy Consumption: Fig. 6 shows the comparison of energy consumption efficiency between "TADR, Dynamic-MobileCC, and CC-RDE". It shows that with the increased data transfer rate, power consumption is also increasing in all the protocol. The CC-RDE, however, is an effective estimate of the delay and the control of the rate transfer method indicates an efficient energy consumption compared to the two comparison protocols.

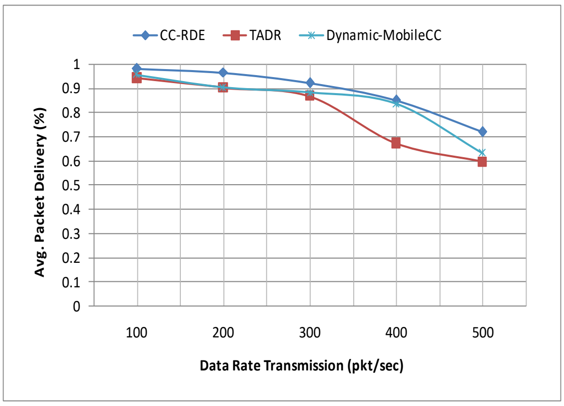

Fig 4. Avg. throughput Comparison

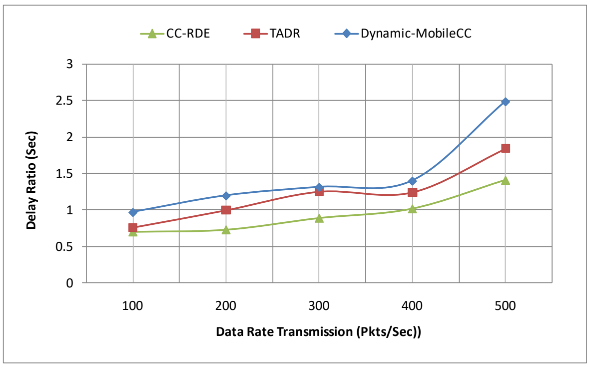

Fig 5. Delay Comparison

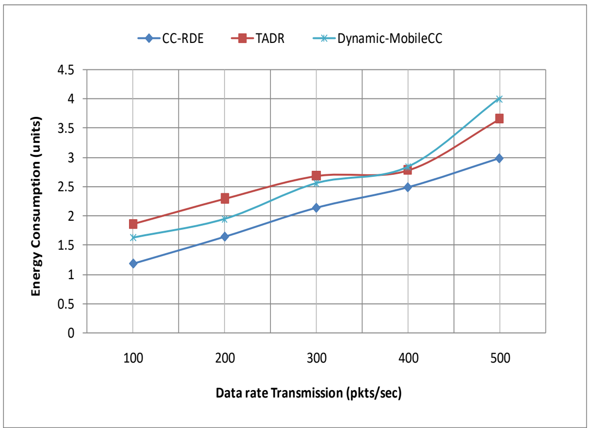

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Fig 6. Energy Consumption Comparison

V. CONCLUSION

The basic difficulty of the dynamic and random behavior of WSN is the loss of packet and congestion. TCP activities are considered through the WSN and its conclusion from the unsatisfactory results of the appropriate TCP mechanism for exceptional WSN quality. In this paper, we propose a congestion control approach by estimating path delay as CC-RDE using buffer length and packet loss to control the data rate of efficiency to reduce packet loss during congestion.

It will efficiently control the data rate of the regular flow application to minimize packet loss and improve productivity. Experimental evaluation with traffic aware and dynamic routing mechanism in an increased data rate traffic shown improvisation in throughput with optimal delay and energy consumption in comparison. Although the proposed CC-RDE mechanism shows a low packet loss due to network congestion and has been evaluated for TCP-based congestion control methods, the impact of DR routing congestion in the effects of data and data rate fluctuations will be the future direction of this work.

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