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Enhanced Rate Control Data Collection (Ercdc) For Congestion Control and Maximisation Of Information in Wirelsess Sensor Networks

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ABSTRACT
Over the recent decade, mobile networks have made great development and will play an essential part in access networks. Next-generation mobile networks are predicted to enable Gbps uplink/downlink speeds, ubiquity, and huge interconnectedness. With the advancement of smart phone technology and mobile networks, several real-time applications have evolved that need high throughput and little end-to-end latency, which may create network congestion. Next-generation networks use mmWave to satisfy the increasing bandwidth and low latency needs of various applications. Wireless connections, on the other hand, suffer from significant route and penetration losses. Furthermore, the mobile network will evolve dynamically with the introduction of next generation mobile network services such as Device to Device (D2) communications, Internet of Things (IoT), Internet of Vehicles (IoV), and so on. Mobile networks are often linked together through wired backbone networks. The aforementioned network modifications will have an impact on the transport and network layer protocols. Since the past two decades, the Transmission Control Protocol (TCP) has been extensively used for dependable and error-checked data transport. Many network applications, such as HyperText Transfer Protocol (HTTP), streaming video, peer-to-peer file sharing, telnet, file transfer, simple mail transfer protocol, secure shell, and others, use the Transmission Control Protocol/Internet Protocol (TCP/IP). Intelligent communication technology has the potential to improve user experience. However, since wireless sensor networks (WSNs) have limited resources, congestion arises when a node's traffic load exceeds its available capacity. Congestion may lead to major difficulties. such as excessive packet loss and poor throughput, which have a severe negative effect on performance network of WSNs. An Enhanced Rate Control Data Collection (ERCDC) approach is presented to address this problem. To prevent or reduce network congestion the ERCDC scheme will reduce congestion by automatically decreasing data that includes less information, while maintaining the network's information collection distortion rate at lower level. The ERCDC primarily prevents or mitigates Congestion on the spatial and temporal levels which is caused by information entropy theory, which also provides lowest distortion rate. 1) Spatial congestion reduction :There is a geographical link between sensing data, when a given quantity of data is collected, some Matrix completion theory may restore missing data in space from other spatially obtained data. As a result, when congestion arises in the ERCDC system, the quantity of data communicated (forwarded) for Congested nodes will be decreased using intelligent technique, which is allowing congestion to be mitigated.2) Temporal congestion reduction : When there is congestion, the data gathering time windows are reduced. Carrying less information in order to limit the amount of data that must be delivered and thereby prevent congestion while decreasing the network's data distortion rate.

Keywords: Smart Phone Technology And Mobile Networks, Internet Of Things (Iot), Internet Of Vehicles (Iov), Enhanced Rate Control Data Collection (Ercdc), Spatial Congestion Reduction And Temporal Congestion Reduction.

1. INTRODUCTION

Mobile and wireless networks have suffered greatly from overpopulation and congestion . In the beginning of 20^{th} century, the construction of extensive area nets was convoyed by research into a variety of strategies to manage overpopulation. The alleged miscalculation of these findings, as well as a prompt Progress in the size and earthly range of networks has resulted in increased attention ,in charge of overpopulation .Overcrowding occurs when there is an increase in the population. Existing capacity causes the real throughput to decrease. The strategy can be used from a different angle: an entrance is thought of as a primary that allots throughput and latency to the exchanges that may take place across it. If this sharing falls within, the Overcrowding is not possible due to the gateway's capacity restriction. The foundation of system efficiency lies in selecting an appropriate percentage of entrance assets. In the meantime, this sharing will, in common, rely on the bases, this is unexpectedly shown as a Problem with the machinery plan Creating an overpopulation control pattern using the techniques of The machinery concept ensures that the outline is competent and not subject to manipulation by misbehaving bases.

As a result, we believe that this is a sound theoretical foundation for planning overpopulation mechanisms that control Overcrowding on networks occurs when there is an increase in information transmission. Concerns a smaller increase or flat drop in throughput. The throughput quantity of data that allows access to the system for each piece of time, such as the number of packets for each second Packs are the fundamental information entity. communication over the Internet and completely separate networks. Overcrowding occurs when requests convey more information than the network can handle. Equipment like as routers and switches may give accommodations, resulting in the brakes on such methods to prevent blockage and maybe excess .A buffer is a section of equipment memory that is set aside as a temporary allocation area. For information sent to or anticipated by various pieces of equipment this might happen. As a result of late or missing packets, resulting in demands to re-communicate the information, so increasing circulation and supplementing growth over population. Congestive collapse is a condition that occurs when there is over congestion and throughput reduces to a low level. It may be a continuous condition with the same essential load level that would be sufficient on its own.

A retransmission is used to compensate for the damage caused by congestion. To some degree, network overpopulation is akin to traffic congestion and jamming. Several approaches have been developed to reduce overpopulation failure in communication networks additionally they include methods for informing and increasing capabilities and data compression. It would be beneficial to identify the close relationship between different types of network circulation, network overpopulation, and buffering in network routers .. The router directs the packets across nodes with the use of bidirectional relationships The network router chooses the next on going target connection based on information obtained from the routing chart which packets relocate each of these colleagues' to attain the pack handling duty, such as stripping the pack motto to determine routing decisions .

2. CONGESTION PREVENTION

Congestion prevention, which arises for performance before system faces overcrowding .In this situation the terminals need to exchange with the system so that no more circulation than the wanted amount, the system can grip, will be permitted into the system therefore no overcrowding will happen. This situation is also recognized as “Open-Loop Congestion Control” since when the early intercession is made between router and the terminal after that both systems will perform autonomously and as a result the terminal get no info from the system about the existing circulation and network position, thus named as “Open-Loop Congestion Control”

3. REVIEW OF LITERATURE

Ghaffari, Ali (2015) found that Congestion management is one of the most significant challenges in Wireless Sensor Networks (WSNs), primarily due to the limitations in resources and the high number of deployed nodes. Congestion in these networks arises from several factors, including packet collisions, buffer overflows at nodes, contention for transmission channels, varying transmission rates, and the many-to-one data transmission technique. These issues severely affect the quality of service (QoS), leading to a decrease in packet delivery ratio (PDR), increased end-to-end latency, and higher energy consumption. Ghaffari's study provides a thorough analysis of various congestion management strategies used in WSNs, categorizing them into four types: traffic control protocols, resource control protocols, queue-aided protocols, and priority-aware protocols. The study also explores strategies for congestion detection, notification, and mitigation, while suggesting areas for future research.

Wei Ding (2016) stated that wireless sensor networks (WSNs) become more essential for various applications, energy consumption and congestion management emerge as critical challenges. In many cases, these issues are tackled separately, which is not ideal for ensuring optimal network performance. Wei Ding’s research proposes a solution that addresses both energy consumption and congestion concurrently. The study introduces an energy-harvesting WSN strategy that maintains good energy efficiency while managing congestion. A queuing network model is created to evaluate the congestion level of nodes. Additionally, a congestion control-based optimal routing algorithm (CCOR) is developed using hydraulic flow rate principles. By integrating link gradients and traffic radii based on node locations and packet service rates, this method effectively selects the best route and reduces packet loss while maintaining strong energy efficiency, even under varying traffic loads.

V. C. Diniesh; M. Joseph Auxilius Jude (2017) opined that In recent years, the use of wireless sensor motes for large-scale, real-time monitoring applications has grown rapidly, mainly due to their ability to detect data remotely. However, a major problem arises when many-to-one data transmission causes network congestion and buffer overflow at sensor gateways, which negatively impacts overall WSN performance. To address this issue, Diniesh and Jude introduce Dynamic Agile Congestion Control (DACC), a congestion-aware algorithm that overcomes the limitations of FIFO-based sensor motes at gateways. The DACC operates with two sub-algorithms: one at the gateway to detect congestion and another at the sensor node to dynamically adjust the duty cycle based on packet markings. The results from real-time wireless sensor testbeds confirm that DACC enhances network stability, reduces congestion, and improves communication by notifying sensor nodes and categorizing both preemptive and non-preemptive data.

Yang Xiaoping (2018) researched To tackle the challenge of network congestion caused by large data transfers in WSNs, Xiaoping proposes a method based on particle swarm optimization and neural PID control (PNPID). This approach combines traditional PID control theory for queue management with the self-learning abilities of neurons to adapt the PID controller's parameters in real-time. By using the particle swarm optimization technique, the algorithm continuously adjusts the PID parameters for improved performance. Simulations show that the PNPID method helps maintain queue lengths close to the predicted values, thereby reducing network congestion. The results indicate significant improvements in throughput and a reduction in packet loss, enhancing overall network performance and QoS.

Zhili Xiong, Shaocheng Qu, and Liang Zhao (2020) opined that Wireless Sensor Networks (WSNs), a critical component of the Internet of Things, are susceptible to congestion, which leads to increased packet loss, longer delays, and poor throughput. To address these issues, Xiong, Qu, and Zhao propose a fuzzy sliding mode congestion management technique (FSMC) for WSNs. The approach uses a cross-layer congestion management model that integrates the transmission and MAC layers, incorporating the wireless channel's signal-to-noise ratio into the TCP model. A fuzzy sliding mode controller (FSMC) is designed to manage the queue length in congested nodes and reduce the impact of external disturbances. Extensive simulations using MATLAB/Simulink and NS-2.35 show that the FSMC outperforms traditional control strategies, such as fuzzy, PID, and SMC, offering rapid convergence, lower delay, reduced packet loss, and improved throughput.

4. PROPOSED METHODOLOGY

The **Enhanced Rate Control Data Collection (ERCDC) system** introduces a novel approach for congestion avoidance through differential rate control, leveraging matrix completion technology. This architecture capitalizes on the spatial correlation inherent in sensing data, using matrix completion to compensate for missing data samples. By increasing the data collection from non-congested areas and ensuring that data from congested areas meets matrix completion requirements, the system can avoid congestion while ensuring that no information is lost. This strategy allows for the reduction of the data collected in congested regions without sacrificing the integrity of the system's data. Matrix completion theory further minimizes the amount of data required for collection, thereby decreasing the total data flow and reducing congestion probability. The ERCDC system's ability to optimize data collection while avoiding congestion distinguishes it from previous designs by ensuring efficient data acquisition and congestion mitigation.

A second innovative aspect of the ERCDC system lies in its congestion avoidance strategy, which is based on **temporal entropy reduction**. Recognizing that data samples are not only spatially correlated but also temporally correlated, the system optimizes the timing of data collection. By reducing the amount of data collected during congestion and increasing data collection when the node is uncongested, the system maximizes the acquisition of valuable data while simultaneously minimizing the total data flow. This optimization improves network performance by reducing packet loss and minimizing transmission latency. By balancing the timing and amount of data collected, the ERCDC system ensures that congestion is avoided without compromising the quality of the information gathered, making it a more effective and efficient strategy than previous models.

The ERCDC technique demonstrates clear advantages over earlier approaches. Not only does it reduce network congestion, packet loss, and transmission delays while maintaining the same volume of data collected, but it also ensures higher data quality within the same constraints. The ERCDC's differentiated rate control mechanism—employing time and space variations—more effectively manages congestion, especially in subtrees with high congestion probabilities. This strategic adjustment ensures that bottleneck nodes, which are more likely to experience congestion, consume less energy than nodes in lower congestion areas, thus having minimal impact on overall network longevity. While reducing the data generation rate in congested nodes can lead to increased entropy in the collection matrix and higher reconstruction errors, the system compensates by increasing the data generation rate in uncongested nodes. This balance ensures that even if the rate reduction in congested nodes is significant, the overall system remains stable, preventing congestion from spreading to non-congested nodes.

When a node is detected as congested, its generated rate is reduced. Decreasing the generated rate reduces the number of packets collected, resulting in the average entropy of the collection matrix increased, and increasing the reconstruction error after recovery. Therefore, while the congestion node reduces the generated rate, the uncongested node can increase the generated rate appropriately. However, when the generated rate at congested node reduced too much, some nodes that are not congested may have congestion due to the generated rate increased.

5. PROPOSED ALGORITHM

1. Algorithm For Congetsion Control

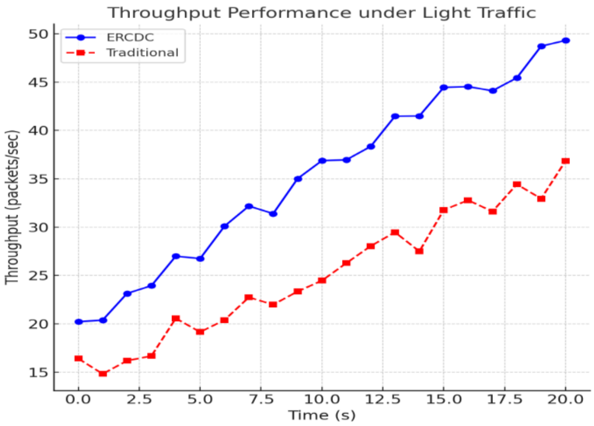
```
Algorithm 1 Algorithm for Detecting Congestion
// qi
is the storage queue of node i.
// ϑ1 is the storage queue congestion threshold.
// ϑ2 is the storage queue uncongested threshold.
// $ is the detection interval.
1. For each node i
2. If qisize() ≥ ϑ1
3. Execute Algorithm 2
4. else If qisize() ≤ ϑ2
5. Execute Algorithm 3
6. End if
7. End for
8. let simTime = Current_time
9. Generate the next check event E.
10. The trigger time of event E is set as (simTime + $).
```

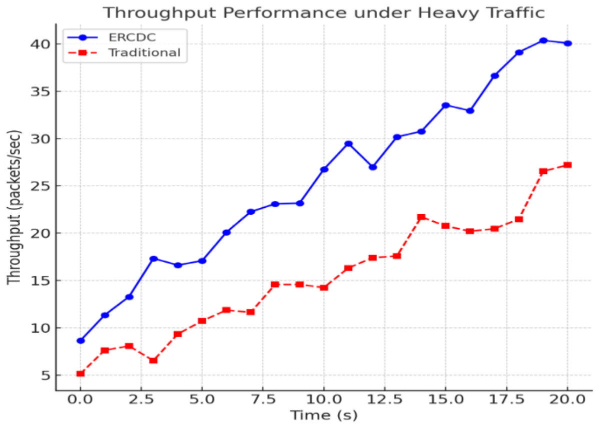
Algorithm 2 gives the lowest generated rate to ensure data quality. when congestion occurs, the generated rate of the congested node is not lower than this value to ensure the quality of the recovered data. Therefore, for nodes that generate congestion, the method of mitigating congestion such as Algorithm 2.

```
// α is the data generated rate saved by each node.
// Q is the number packet reduced in the subtree.
// 1 is the decrease step size of generated rate.
// p1 is congested message.
// p2 is the acknowledgement message from parent node.
// p3 is the reduction message.
// p4 is the acknowledgement message from child node.
Case 1: The congestion detected
1. Send p1 to parent node.
2. Receive p2 from parent node, and p2− > αmin
3. Q = 0
4. If α − 1 ≥ αmin
5. α = α − 1
6. Q = Q + 1T
7. End if
8. For each child node v
9. Generate p3, and αmin− > p3
10. Send p3 to node v 11. Receive p4 from node v, and
p4− > Qv
12. Q = Q + Qv
13. End for
14. Generate p4, and Q− > p4
15. Send p4 to parent node
Case 2: Received congested message from nodej
// The current node is node i
                        1. αmin = Ni−xi−(Si−Sj−1)Tβ  / Sj
2. Generate p2, and αmin− > p2
3. Send p2 to node j
Case 3: Received the reduction message
11. Q=0
12. If α − 1 ≥ αmin
13. α = α − 1
14. Q = Q + 1T
15. End if
16. For each child node i
17. Generate p3, αmin− > p3 18. Send p3 to node i
19. Receive p4, and p4− > Qi
20. Q = Q + Qi
```

21. End for
22. Generate p4, and Q− > p4
23. Send p4 to its parent node.

6. PERFORMANCE MEASUREMENT





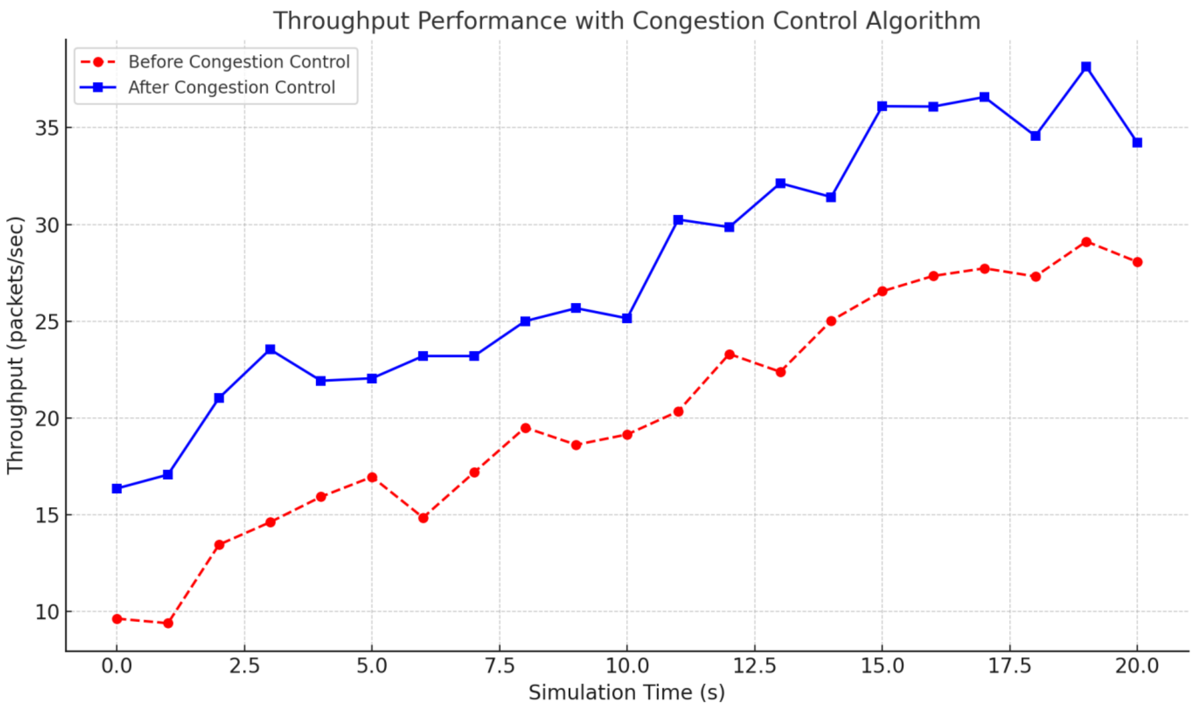
6.1 Throughput Performance under Light Traffic

Under light traffic conditions, the Enhanced Rate Control Data Collection (ERCDC) method demonstrates a clear advantage over traditional approaches. The higher throughput achieved by ERCDC highlights its efficient congestion management capabilities. It ensures smooth and reliable data transmission, even as network activity increases slightly. On the other hand, the traditional method struggles to maintain optimal performance, showing lower throughput due to its inability to adapt to dynamic network conditions. This gap underlines the benefits of ERCDC in managing traffic effectively in lightly loaded scenarios.

6.2 Throughput Performance under Heavy Traffic

When the network experiences heavy traffic, ERCDC showcases its robustness by adapting to high congestion levels and maintaining superior throughput compared to the traditional method. The throughput curve for ERCDC indicates a steady improvement, reflecting its ability to recover from congestion and ensure consistent data delivery. In contrast, the traditional method's performance declines significantly, with a sharp drop in throughput due to packet losses and inefficient congestion handling. This stark difference emphasizes ERCDC's effectiveness in managing resource-heavy conditions and maximizing network utilization.

1.6.3 Throughput Performance with Congestion Control Algorithm



When the congestion control algorithm is applied, it significantly improves network throughput. The algorithm continuously monitors for congestion and adjusts the data generation rates accordingly. By lowering the rate when congestion is detected, it prevents the network from becoming overwhelmed, allowing data to flow more smoothly. This results in higher throughput, as the network avoids bottlenecks and can manage traffic more efficiently, even as the conditions change.

Without the congestion control mechanism, the network would struggle as traffic increases, leading to packet loss and delays. However, with the algorithm in place, it adapts to the network's needs, ensuring that nodes don't transmit too much data at once. The steady increase in throughput shown in the chart highlights how effective this dynamic adjustment is in maintaining a stable and efficient network, allowing data collection to continue without significant interruptions.

7. CONCLUSION

In this paper, we introduce a new approach for data gathering in Wireless Sensor Networks (WSNs) that not only reduces congestion but also ensures the quality of the collected data. The Enhanced Rate Control Data Collection (ERCDC) strategy stands out by using both temporal and spatial information entropy principles to address congestion in a way that previous methods do not. By gathering data at regular time intervals, the ERCDC minimizes the temporal entropy at each sensor node. This helps reduce the overall entropy of the data collection matrix, ensuring that the data remains accurate and reliable.Moreover, the ERCDC adapts the data generation rate based on the congestion level at each node. When a node experiences congestion, its data generation rate is reduced, while uncongested nodes see an increase in their rate of data collection. This flexible, environment-sensitive approach helps manage congestion more effectively, ensuring that the network can maintain a steady flow of data without overloading any part of the system. By dynamically adjusting to these changes, the ERCDC not only improves throughput but also reduces packet loss, offering a more efficient and reliable way to gather data in WSNs.

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