Abstract: In present day wireless communication applications the congestion is vital factor to be considered for ensuring efficient data communication. Novel applications introduce much heavier traffic load, which, in turn, leads specific areas in the network to face congestion problems. Here in this research work we propose to develop a highly robust and efficient congestion control and mitigation system to mitigate congestion in highly congested WSNs under specific circumstances. In this research work we examine the benefits of introducing new mobile nodes placed between the congested areas and sinks, in order to provide alternative disjoint paths towards them. The Mobile Congestion Control (Mobile-CC) algorithm is applicable in areas where congestion happens repeatedly, or is of high duration, or even permanent. If congestion happens for very small period of time there will be no big benefit (in terms of congestion mitigation) when moving any nodes to that area, unless there is great probability of the event happening again at the same place in the future. Mobile-CC is not replacing existing congestion control or routing algorithms but instead aims to mitigate congestion, running in parallel with them. The proposed system emphasizes its robustness for ensuring higher throughout, least data drop and regeneration and higher packet delivery ratio under varied network configurations, like multiple sensors (static and mobile nodes), dynamic behaviour of nodes in communication region etc.

Keywords: Wireless Sensor Networks, Mobile Sensors, Multipath Routing, Congestion Mitigation, Hard Alternative Disjoint Path (HADP).
1. Introduction:

Wireless Sensor Network: A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. In present day wireless communication applications, WSNs have potential contribution for varied applications and critical utilities. In general there are numerous applications where WSNs might face congestion problems when certain event takes place and a huge amount of information needs to be transferred towards the sink(s) or base station. As soon as the congestion takes place or arises in network for some period, the queues of some nodes might cause overflow and packets will be randomly dropped. Due to such unwanted dropping of critical data packets in communication network the critical information is lost in its way to base station or sink node and consequently the retransmission of data packets becomes inevitable. This is also a matter of fact that data drop and even regular data drop might reduce network performance to a great extent. The regeneration of data and further retransmission also causes huge energy consumption. In order to avoid such performance degradation and losses, the wireless communication network must be capable of either to avoid being in this state or to identify the congestion and recover (self-heal) in order to stop loosing valuable information.

A number of researches have been done for congestion detection and mitigation but majority of the existing approaches do suffer from certain limitations such as employing extra WSN nodes in network might cause extra energy consumption and even cost factor gets increased. In some works variable buffer window were employed but it is capable for a small network size and eve it cannot ascertain optimal result in case of huge data sets and regular congestion scenarios. In any congestion control algorithm there is usually a congestion detection mechanism which initiates some tasks to react to the congestion. Some congestion detection mechanisms may assume that congestion is happening by observing the number of messages in the buffer of a node and if this reaches a threshold they ”switch on the congestion alarm”, while some others may assume that congestion occurs after a number of retransmissions due to non acknowledged reception.
In this research or project work we have developed a highly efficient and robust mechanism of congestion detection and mitigation using mobile nodes in Wireless Sensor Networks.

Here in our project we have described and developed a Mobile-CC mechanism specially designed for assisting congestion mitigation in wireless sensor networks (WSNs). In our proposed system model the initiation of the mechanism takes place when the congestion detection mechanism indicates that congestion is happening. In our proposed Mobile-CC the detection has been simulated randomly and the complete WSN network has been simulated on MATLAB software tool. The detection of congestion in any network can be accomplished by means of evaluation of the buffer occupancy and received data rate.

The fundamental foundation of our unique system model is that in our work, we are developing our system in such a way that whenever there is any congestion in the network, the sink node ignites or activates or sends a mobile node at the rear of the node suffering from congestion. In our proposed system model, Mobile-CC scheme, a number of mobile nodes placed behind the sink(s) are sent by the sink(s) to create Hard Alternative Disjoint Paths (HADPs) in order to relieve a specific area from congestion.

In our proposed system, as soon as the congestion has been detected the Congestion Detection Messages (CDMs) are sent to the sink(s) containing information that are used by the sink(s) in order to decide how and where to build the alternative paths in order to mitigate congestion at the congested areas. When a sink takes such a decision, it informs a number of mobile nodes residing behind it to move to specific locations. When the mobile nodes reach the target location, they turn on their radio, and form a Hard Alternative Disjoint Path. The reason that these paths are called “Hard Alternative Disjoint Paths” is because only mobile nodes are involved in these paths and no other existing node, besides the predefined by the sink senders. As a result some of the senders, who congest other nodes, use these hard alternative paths for forwarding their packets, and this tactic results in congestion mitigation.

The proposed system model or algorithm needs both mobile and fixed nodes to be aware of their location. For the purpose of this proposed system, an assumption is done that all nodes in the network are able to know their location.

The proposed system model has been developed with MATLAB software tool and its communication toolbox interface. The system performance would be analyzed in terms of throughput, success ratio of data packet, data drop ratio and congestion mitigation success ratio.
1.1. Congestion In Node Level:

The node level congestion occurs when the access the same transmission media. In Rate Adjustment Technique algorithm the scheduling rate and source rate in single path routing were explained in detail. Normally high congestion occurs in upstream traffic because it is many to one principle. In CAR protocol the packets are routed based on priority. Depend on the priority the packets are routed in a special zone (or) out of that zone using CAR protocol.

1.2. Upstream Congestion Control:

The upstream congestion control is classified as three types names as event-based, continues and hybrid. In event based the sensor node reports to sink node based on event. In query based type the sensor nodes are asked query y sink node. In continues type the sensor nodes periodically reports to sink node. In case of hybrid approach all three types included. The HCCP is used to control congestion in WSN based on buffer size. In above mentioned figure (Fig 1) the node level congestion is illustrated clearly. The PSFQ is used to analyze reliable data transport in WSN. In this approach if the neighbor nodes forward same packet it stops forwarding. It maintains cache table for maintain unknown packet details. The input rate, forwarding rate and scheduling rate are considered for congestion control. There are two types of traffic in WSN called transit and source. The source traffic occurs in sensor nodes whereas the transit traffic occurs in other nodes. All these traffics are entered into network layer.

1.3. Congestion Control In Node Level:

It is important to design MAC layer properly to avoid queue formation. The network management of sink node affects the other nodes. In spite of various congestion control algorithms are used it is important to design the protocol. In Dynamic Contention Window Control the buffer overflow is controlled by identifying highly loaded nodes. The efficiency, fairness and energy dissipation should be calculated properly. In order to get high efficiency the number of hops should be high than number of transmissions. Our motivation is to avoid packet loss and buffer drops by designing proper congestion control techniques.
2. Development Of System Model:

2.1. High Level Design:

In wireless sensor networks (WSN), each sensor individually senses the environment, but collaboratively achieves complex information gathering and dissemination tasks. Typically wireless sensor network follows the communication pattern of converge cast, where sensors collect data about a phenomenon and relay streams of data to a common static sink node. Depending on the application requirements, we can mention about three basic data delivery models:

a. Periodic sensing: sensors transmit the collected data continuously at periodic intervals,

b. event-driven: sensor nodes report data only if an event of interest occurs, and

c. Query-driven: sensors only report data in response to an explicit request from the sink.

2.2. Design Consideration:

In this proposed system, we describe the Mobile-CC mechanism designed to assist in congestion mitigation in wireless sensor networks. The initiation of the mechanism takes place when the congestion detection mechanism indicates that congestion is happening. In Mobile-CC the detection is done based on the buffer occupancy and received data rate. The Congestion Detection Mechanism is explained in detail in the algorithm description section of the paper. In Mobile-CC a number of mobile nodes placed behind the sink(s) are sent by the sink(s) to create Hard Alternative Disjoint Paths (HADPs) in order to relieve a specific area from congestion. When congestion is detected Congestion Detection Messages (CDMs) are sent to the sink(s) containing information that are used by the sink(s) in order to decide how and where to build the alternative paths in order to mitigate congestion at the congested areas. When a sink takes such a decision, it informs a number of mobile nodes residing behind it to move to specific locations. When the mobile nodes reach the target location, they turn on their radio, and form a Hard Alternative Disjoint Path. The reason that these paths are called “Hard Alternative Disjoint Paths” is because only mobile nodes are involved in these paths and no other existing node, besides the predefined by the sink senders.
2.3. Development Method:

This project would follow Iterative Development Methodology. This would enable the product to be built in increments. Rational Unified Process (RUP) would be the approach to manage the development process of the project. The RUP is not a single concrete prescriptive process, but rather an adaptable process Framework. It encompasses a large number of different activities; it is also intended to be tailored, in the sense of selecting the development processes appropriate to a particular software project or development organization. The RUP is recognized as particularly applicable to larger software development teams working on large projects.

The advantages of the iterative process model are:-

a. It is easier to accommodate the changes in requirement at alter stage.

b. It is easier to control the risk. The higher risk areas are addressed in the beginning of the project.

Incorporation of the feedback of iteration into subsequent iterations will make the quality of the product better.

a. The best practices of Rational Unified process are:-

b. Develop software iteratively

c. Manage requirements

d. Use component based architecture

e. Visually model software

f. Verify software quality

g. Control changes to software

The purpose of the design phase is to plan a solution of the problem specified by the requirement document. Design is a creative process; a good design is the key to effective system. The word “Design” is defined as “The process of applying various techniques and principle of the purposes of defining a process or a system in sufficient detail to permit its
physical realization”. This phase is the first step in moving from the problem domain to the solution domain. The design of the system is perhaps the most critical factor affecting the quality of the software. Various design features are followed to develop the system. The design specification describes the features of the system, the components or elements of the system and their appearance to end-users.

3. Fundamental Design Concept:

3.1. Input Design:

Creating a working implementation of Mobile-CC algorithm, we give the simulation parameters (no of nodes, data rate, and buffer occupancy) which are the inputs for different types of mechanism such as congestion detection mechanism, congested node selection mechanism, congestion notification mechanism and reaction mechanism to achieve the goals. In the proposed system model, the system functions on the basis of defined nodes in communication environment and for these varying mobile nodes, static sensor nodes have been defined. The velocity factor has also been considered in communication network which decides the velocity of mobile nodes in the communication scenario. Higher the velocity more mobility of mobile nodes would take place.

3.2. Output Design:

In this proposed system, Mobile Congestion Control algorithm, is proposed to mitigate congestion. The proposed scheme achieves the congestion mitigation in wireless sensor network where congestion happens repeatedly and results will be taken concerning throughput and dropped packets. The system model in this proposed research has been developed with taking into consideration of the predominant requirement to enhance the throughput of the wireless sensor network by increasing success ratio of transmitted data packets, reducing packet drop ratio and then optimizing congestion mitigation.
4. Proposed System:

![Diagram showing the proposed system]

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senders. As a result some of the senders, who congest other nodes, use these hard alternative paths for forwarding their packets, and this tactic results in congestion mitigation. The proposed algorithm needs both mobile and fixed nodes to be aware of their location. For the purpose of this proposed system, an assumption is done that all nodes in the network are able to know their location. Localization of node and path planning are two issues that are beyond the purpose of this proposed architecture.

5. Implementation:

In the proposed system, we describe the Mobile-CC mechanism designed to assist in congestion mitigation in wireless sensor networks. The initiation of the mechanism takes place when the congestion detection mechanism indicates that congestion is happening. In Mobile-CC the detection is done based on the buffer occupancy and received data rate. The Congestion Detection Mechanism is explained in detail in the algorithm description section of the proposed system. In Mobile-CC a number of mobile nodes placed behind the sink(s) are sent by the sink(s) to create Hard Alternative Disjoint Paths (HADPs) in order to relieve a specific area from congestion. When congestion is detected Congestion Detection Messages (CDMs) are sent to the sink(s) containing information that are used by the sink(s) in order to decide how and where to build the alternative paths in order to mitigate congestion at the congested areas. When a sink takes such a decision, it informs a number of mobile nodes residing behind it to move to specific locations. When the mobile nodes reach the target location, they turn on their radio, and form a Hard Alternative Disjoint Path. The reason that these paths are called “Hard Alternative Disjoint Paths” is because only mobile nodes are involved in these paths and no other existing node, besides the predefined by the sink senders. As a result some of the senders, who congest other nodes, use these hard alternative paths for forwarding their packets, and this tactic results in congestion mitigation. The proposed algorithm needs both mobile and fixed nodes to be aware of their location. For the purpose of this proposed system, an assumption is done that all nodes in the network are able to know their location. Localization of node and path planning are two issues that are beyond the purpose of this proposed architecture.
5.1. Step 1- Selection Of Platform:

Windows® XP present the major reliable edition of Windows constantly with the most excellent security as well as privacy features Windows has always presented. On the whole, security is enhanced inside Windows XP to assist you have a secure, safe, as well as confidential computing occurrence.

5.2. Step 2 – Selection Of Language:

For the implementation of this development we required supple systems implementation language. Compilation ought to be comparatively uncomplicated compiler, present low-level entrance to memory, present language build that map professionally to machine instructions, as well as necessitate minimal run-time hold up. Program ought to be accumulating for an extremely wide diversity of computer platforms as well as operating systems with least modify to its source code. For the Graphical User Interface (GUI) programming, language preferred must be easy to employ, secure, structural design neutral as well as portable. Further necessities of GUI are:

a. User interface management: Windows, menus, toolbars as well as additional presentation mechanism be hold up by the language.

b. Data and presentation management: language is necessity enclose a wealthy toolset for proposing data to the user as well as influence that data.

c. The Editor: The language is supposed to contain an editor, an influential and extensible toolset for constructing convention editors.

d. The Wizard Framework: A toolset for effortlessly making extensible, user responsive Wizards to direct users during additional multifaceted responsibilities.

e. Configuration management: somewhat than boringly put in writing code to admittance remote data as well as handle and save user-configurable settings, et cetera. The entire of this is being able to be glowing managed by Matlab. Consequently Matlab is preferred for the GUI improvement.

5.3. Step 3- Coding Guidelines:

The subsequent are the guiding principle subsequent throughout the implementation of the development of the project.
a. Initialize the entire member data as well as confined variables. Every pointers ought to be initialized to apposite values or NULL.

b. A counter variable that is utilize merely in for loop must be initialized inside that loop, relatively than on the top of the function, where, variables confirmed in nested loops determination be frequently constructed as well as destructed. During cases where building or destruction is costly, it might be preferable to affirm the variable outside the loop.

c. Utilize tracing declaration at serious points inside the code.

d. For the entire of data kind definition has been utilized.

e. The total message configure is accumulated in header file.

f. The entire functions must not go beyond more than 100 lines.

g. Function pointers are not used.

h. All the code should be properly indented

i. Use conditional compilation statements wherever required

5.4. Step 4- Implementation Strategies:

In this section we propose a new technique for WSN and explain it. This method supposes that nodes moves around and relay each other packet in a circular environment. This circle is divided into equal sectors and cylinders. Each area has a unique id. We assume a central point in each area. Nearest nodes to this central points in each area are selected as local server. Each local server is responsible for response to location queries for all owner member nodes. Location update packages move along the cylinder and location query packages move along the sector. These update and query propagation method decrease system response time, because the query packet traversed only one sector.
Figure 2: Network model

Sectors are numbered respectively. One of the sectors is considered as basic sector. Location servers in basic sector periodically start to send location update packets in two directions. These packages gather updates of local servers from each area. All packages are sent by geographic method.

Network area is modeled as a circle-shaped. This circle is divided into cylinder and sector. Each area is created by intersection between sectors and cylinders. Each node at any moment can stay in one of these areas. The follow description is about how to divide this areas. Lets we assume that the radius of network area is "R" and the radius of radio broadcasts of each node is "r". Size of each zone must be set so that all nodes within that region will be in radio broadcast of local area server. Due to the local servers are located approximately at the center of each area, so the maximum size per area can be 2r. But because at the worst case the local server may not be located in the middle of area and may be in one of the corners, we assume the size of arc in each area can be "r". Then all the nodes within the area are in location server radio broadcasts. So if we show the sector number "n" and the number of cylinders "m" and size of each sector with angle "β". These parameters have been obtained from the following equation:

\[ n = \frac{(2\pi R)}{r} \]
\[
m = \frac{R}{r}
\]
\[
\beta = \frac{360}{n} = \frac{360r}{2\pi R}
\]

Assuming that each node can locate its location information with using location tools. So it can obtain own polar coordinates \((a, \alpha)\) from center of network area. Each area with region \((p, q)\) is defined as the sector numbers "p" and cylinder number "q". This parameter has been achieved using the following expression:

\[
\text{Region}(p, q), p = \text{Div}(\alpha/\beta), \text{and } q = \text{Div}(a/r)
\]

5.5. Step-5 Software Implementation:

This section introduces the software product. This system requirement specification states a basic document that constitutes the foundation of the system development process. Software requirement specification (SRS) represents the needs of certain model development process. The software requirement specifications represent the organizations perceptive of a customer or prospective client’s system needs dependencies at a certain time or instant previous to any kind of factual development procedure. On the other hand, software requirement specification also functions as an outline for accomplishing certain objective of a project with minimum cost expenditure. It is also significant to consider that the comprises functional and non functional requirements only; it doesn’t offer any design recommendations, probable results and paradigms for problem solving, or business issues or any other kind of information except the development team recognizes the requirements of customer’s system.

1. Development Algorithms And Applications:

MATLAB present a high-level language as well as improvement tools so as let single quickly build up and examine the algorithms as well as applications.

6.1. The MATLAB Language:

The MATLAB language ropes the vector as well as matrix operations that are essential to engineering along with technical troubles. It facilitates speedy improvement and implementation.
Through the MATLAB language, individual preserve program as well as build up algorithms earlier than with conventional languages because single do not required performing low-level governmental tasks, such as pronounce variables, identifying data kinds, along with distributing memory. In several containers, MATLAB remove the required for ‘for’ loops. As a consequence, single line of MATLAB code can frequently replace numerous lines of C or C++ code. By the similar time, MATLAB present each and every features of a conventional programming language, including mathematics operators, flow control, data structure, data kind, object-oriented programming (OOP), as well as debugging features.

Figure 3

Figure 3 A communications inflection algorithm which produce 1,024 random bits, present modulation, adds compound Gaussian sound, as well as plots the result, every in presently 9 appearance of MATLAB code.

MATLAB lets single perform commands or assemblage of commands individual by a time, with no compiling with linking, enabling single to rapidly iterate to the best solution.

For speedy execution of important matrix along with vector computations, MATLAB employ processor-optimized libraries. For general-purpose scalar calculation, MATLAB produces machine-code commands utilizing its JIT (Just-In-Time) collection equipment. This machinery is obtainable on the majority of platforms, afforded execution velocity that rivals those of established programming languages.

6.2. Development Tools:

MATLAB incorporate improvement tools that assist individual to execute their algorithm professionally. These incorporate the subsequent:
a. MATLAB Editor: presented standard suppression along with debugging features, like a setting breakpoints with particular stepping  

b. Code Analyzer: ensures the code for troubles and advocates alteration to make the most of presentation and maintainability  

c. MATLAB Profiler: proceedings the time expend executing every row of code  

d. Directory Reports: Scan every the files inside a index and report on code competence, file dissimilarity, file dependency, as well as code coverage  

2. System Testing:  
The aim of testing stage is to discover defects/errors by testing individual program components. These components may be functions, objects or modules. During system testing, these components are integrated to form the complete system. At this stage, testing should focus on establishing that the system meets its functional requirements, and does not behave in unexpected ways. Test data are inputs which have been devised to test the system whereas test cases are inputs to test the system and the outputs are predicted from these inputs if the system operates according to its specification. This is to examine the behavior in a cohesive system. The test cases are selected to ensure that the system behavior can be examined in all possible combinations of conditions.  

Accordingly, expected behavior of the system under different combinations is given. Therefore test cases are selected which have inputs and the outputs are on expected lines, inputs that are not valid and for which suitable messages must be given and inputs hat do not occur very frequently which can be regarded as special cases.  

7.1. Test Environment:  
The software was tested on the following platform.  

7.1.1. Hardware:  
250 GB Hard Disk, Min 1 GB RAM with 1.84 GHz Dual Core processor
7.1.2. Software:

   a. Operating System – Windows XP (32 bit and 64 bit), Windows7
   b. Matlab 2012b

3. Results And Analysis:

In this proposed research work a highly robust and efficient algorithm for congestion detection and mitigation in wireless sensor network (WSN) has been developed. The predominant characteristics of the proposed system is that in this approach after getting the congestion detection acknowledgement the base station or the sink ignites or introduces multiple mobile nodes in certain congested region and nodes do move towards congestion region. Once the mobile nodes approaches in the range of congestion nodes, it makes its radio ON. Thus, the introduced hard alternative disjoint path (HADP). Forming HADP, the links created do transfer the data to the destination of base station through HADP. Thus, it causes reduction in congestion on suffering nodes. The proposed system encompasses multiple models such as congestion detection and acknowledgement message, congestion mitigation or reaction mechanism. For congestion detection multiple factors such as buffer occupancy, data rate etc can be taken into consideration. The proposed system has been prepared with a goal to introduce it as a parallel system to mitigate congestion in wireless sensor network where there are regular probabilities of congestion. The simulation framework has been designed for varied node size, node density and region space. Ultimately, the simulation results have been achieved in terms of packet delivery ratio depicting total success rate, received packet ratio and ultimately congestion mitigation ratio.

The simulation framework developed and results obtained are given as follows:
Figure 4: Main GUI of project

Figure 5: Simulations in Progress
Figure 6: Analysis of Packet Delivery ratio

Figure 7: Analysis of Received packets
4. Conclusion:

In this research or project work the concept of employing multiple mobile nodes for creating alternate disjoint paths towards the destination in wireless sensor network (WSN) has been proposed. In this work the author has developed a highly robust and efficient distributed congestion detection mechanism that enables congestion detection on the basis of sending rate of upstream nodes and the buffer occupancy of a receiving node. Additionally, a distributed congested node selection scheme has also been proposed for deciding which nodes to keep serving and when a node detects that is congested. Ultimately, a congestion notification approach that facilitates priority to CDM messages has been taken into consideration. In this work, the author has made the system capable of handling congestion monitoring, control and congestion mitigation system with the help of multiple or varied mobile nodes and with varying topological circumstances such as number of static nodes, number of mobile nodes and geographically partitioned area of zone, which has been referred as cylinder representing a particular area where the nodes exist. In order to monitor and mitigate the congestion in network a robust and automatic Hard Alternative Disjoint Path (HADP) has been formed. In the simulation framework sink or base station after getting congestion information, initiates multiple mobile nodes which later becomes ON only after
coming into the radio range of congested node. Thus, being greedy in nature, some of the nodes do transfer their data packets to the newly constructed HADP and thus the load at the congested node becomes under control. This not only ensure negligible data drop but also enhances energy consumption in data transmission and retransmission.

Simulation results exhibited that by adding HADPs starting near congested nodes and extending towards the sinks in areas where congestion appears for a long period of time results in congestion mitigation. As a result the throughput of the network was increased dramatically and in addition packet drop reduction was obvious. Future work includes a clear definition of the Reaction Mechanism in which the sink decides how and where to build the paths and how mobile nodes introduce themselves to the network securely. Furthermore, other parameters like the node locations and the path energy profile can be considered in the decision of the congested nodes on which sender nodes to keep.

The proposed system can further be enhanced in terms of a highly robust and efficient reaction mechanism in which the sink would decide how and where to build the paths and how mobile nodes introduce themselves to the network securely is not considered. Even in this work, node localization and path energy profile has not been taken into consideration, so in future the system can be further enhanced by maintaining node tables and other parameters. To improve the performance during congestion, a multi-queue-LIFO (Last-In, First-Out) approach can be used. To further enhance the fairness performance, the single queue in each node can be divided into multiple weighted sub-queues logically, and forward packets in each sub-queue based on its weight. This method can effectively balance the data reception from other nodes at the BS. Both theoretical analysis and extensive experiments can be performed to verify the performance improvement of this approach, etc.
References:


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