# Data Over Tree Based Topology in Wireless Sensor Networks

**G.V.S.Krishnapriya[1] and Mrs. S. Rama Sree[2]**

**1. M.Tech Degree in Computer Science Engineering, Aditya Engineering college, Kakinada, India.**
**2. Professor & Head of the Department of Computer Science & Engineering at Aditya Engineering college, Kakinada, India.**

**Abstract: T**he technique is to combine the scheduling with transmission power control to reduce the effects of interference. To better cope with interference, we then study the impact of utilizing multiple frequency channels by introducing a simple receiver-based frequency and time scheduling approach. We find that for networks of about a hundred nodes, the use of multi-frequency scheduling can suffice to eliminate most of the interference. The data collection rate then becomes limited not by interference, but by the maximum degree of the routing tree. Therefore we consider finally how the data collection rate can be further enhanced by the use of degree-constrained routing trees. Considering deployments at different densities, we show that these enhancements can improve the streaming aggregated data collection by as much as 10 times compared to the baseline of single-channel data collection over non-degree constrained routing trees. Addition to our primary conclusion, in the frequency scheduling domain we evaluate the impact of different interference models on the scheduling performance and give topology-specific bounds on time slot and frequency channel requirements.

***Keywords*: Converge cast, Multi-channel, Topology, Energy, TDMA.

## I. Introduction

A tree base sensor network is a collection of sensors nodes, such as sink is the root of tree and leaves are the nodes. Data in such topology flows from sensor nodes (leaves) to the sink (root) of the tree. Collection of data from a set of sensors to an intermediate parent (sink) in a tree is known as converge-casting. The ‘delivery-time’ and ‘data-rate ’ are application specific. As an example, in oil and gas refineries the sensor devices and controllers need to collect data from all the sensors within a specific deadline for any kind of leakage or failures. Whereas applications like weather for-casting, under-water observations needs continuous and fast data delivery for analysis, for longer periods. Here in this paper our emphasis is on such applications focusing on fast data streaming from sensor to sink node. The two common approaches for data collection [3] are – aggregated-data converge cast where packets are aggregated at each hop, and raw-data converge cast where each data packet travel towards sink node individually. First approach is most suitable where data is highly co-related and objective is to collect maximum sensor reading and second approach is used where the reading of each sensor is equally important. Further, interference and network topology are the two prime limiting factors in wireless sensor networks. Time Division Multiple Access (TDMA) [2] protocol is well suited to periodic data traffic to have contention free medium and to avoid collisions. The use of multiple frequency channels can allow more concurrent transmissions. Here we have shown that if multiple frequencies are employed along with TDMA, the data collection rate is affected by tree topology and not by interferences. Thus, in this paper we identify the effect of network topology on the schedule length, and analyzed the performance of converge cast by using multiple frequencies as compared to those trees using a single frequency. The rest of the paper is organized as follows: in Section II, we discuss related works. In Section III, we describe system modeling and some discussions. In Section IV, we have shown multichannel scheduling for interference elimination. In Section V, we focus on impact of network topology on data forwarding. Section VI gives the evaluation work based on previous discussions. Finally Section VII concludes the paper.

The remainder of the paper is organized as follows: in Section II we explain the mechanisms that we use to investigate the scheduling performance. Section III discusses different design possibilities on modeling co-channel and adjacent channel interference. Section IV presents the possible upper and lower bounds on the time and frequency requirements. Section V gives the detailed simulation based evaluation of the discussed methods. Section VI summarizes some of the related work. Finally, Section VII provides the concluding remarks

**Mode of Action**: Preliminaries before explaining the studied mechanisms, we first express the preliminary design details and assumptions

- We consider a static wireless sensor network. The sensor nodes periodically sense the environment and send their readings over a multi-hop tree topology.

- Time is divided into equal sized slots that are grouped into frames. We focus on minimizing the length of the frame such that each node is assigned one time slot.

- We consider minimum-hop routing trees where all the nodes select a parent node where they transmit their readings to be forwarded towards the sink node.

- We assume all the nodes in the network are sources and the data is aggregated such that the data coming from different sources are combined into a packet(s) before forwarding.

If the incoming packets cannot be combined in a single packet and multiple packets have to be forwarded, we assume each time slot is long enough to transmit those packets. This is a reasonable assumption since the size of the sensor readings is usually very small. Figure 1 shows the relationship between the schedule length and the aggregated data rate. The numbers on the links show the assigned time slots and the numbers inside the circles represent the node id’s. On the left of the figure we see the schedule showing the received packets from the associated senders by each parent on each time slot. After frame 1, once the sink gets initial data from each source (a pipeline is established), the same schedule is repeated and the sink collects the aggregated data from the network at a rate of 3 time slots. Thus, the schedule length should be minimized to improve the data collection rate

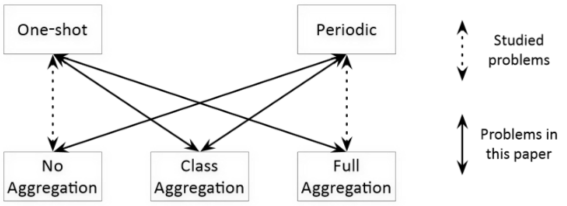
**Work Module**: Lets proposed a distributed time slot assignment scheme, for a single channel in TDMA schedule length. Fast data collection with minimum schedule length for aggregated converge cast is discussed the concept of orthogonal codes to remove interferences, where each node has been assigned time slots from bottom to the top of the tree such that a parent has to wait till it receives all the data packet from its children. Pan and Tseng described a beacon period, assigned to every sensor node in Zig bee network, scheme to reduce latency. A node can receive data only in the allotted beacon period. Song et al.[6] described a time optimal energy efficient packet scheduling algorithm for raw-data converge cast with periodic traffic. They assumed a simple interference model in which every node has a circular transmission range and interferences from concurrent multiple senders is neglected. further extended their work and proposed a TDMA- based MAC protocol for high-data-rate. Shows that for a single channel the minimum schedule length for raw-data converge cast is NP complete on general graphs uses agreed graph coloring approach to find the shortest path to the senders for throughput optimization. They also focused on impact of routing trees on schedule length and devised a new approach called disjoint strips to transmit data over different shortest paths. The use of multiple frequencies is widely described.

## SYSTEM MODELING AND DISCUSSION

Let G = (V, E) is a multi-hop WSN graph, where V is the set of sensor nodes, and E = (I, j) : (I, j) Є V is the set of wireless links. Lets is the sink node such that ЄV. The distance between two nodes I and j is denoted by dig. All the nodes other than generate and transmit data packets through a network path to sinks. Let, T =(V, ET) is a spanning tree on G where ETE and represents the tree edges. It is assumed that each node has half duplex transceiver; therefore it cannot simultaneously send and receive data. We have used equal sized timeframe TDMA protocol and two types of interference models for analysis namely: SINR based physical model and graph based model. The interference range of a node is equal to its transmission range which means two links cannot be scheduled at the same time if receiver of one link is within the transmitter range of the other link. In SINR model the successful reception of a packet from i to j depends on cumulative interference caused by all concurrent transmitting nodes and the ratio between the received signal strength at j. The size of each data packet is assumed to be same. For fast data routing we aim to schedule the edges ET of T using a minimum number of time slots with two constraints Adjacency constraint it states that two edges in ET cannot be scheduled in same time slot if they are adjacent to each other. This is because of half duplex transceiver available on nodes. Interfering constraint. The interfering constraint depends on the choice of the interference model. For a periodic data collection in aggregated converge cast each edge in ET is scheduled in a pipeline manner. The sink receives packets from the pipeline one after another. On the other hand, for raw data converge cast the edge in ET is scheduled multiple times hence no pipeline

### Raw-Data Converge cast:

Data gathering or converge cast in wireless sensor networks is a many-to-one communication pattern in which sensors send data to a base station or sink. Each sensor node operates as a data source and/or relay node to pass along data items. A routing tree, specifying paths from all source nodes to the sink, is derived from the connectivity graph of the underlying network. Data at each sensor node is forwarded on to the parent within the tree, until reaching the root, i.e., the sink. Due to the broadcast nature of wireless communication, interference may occur when multiple sensors transmit data simultaneously, causing the interfering packets to fail. The links of the routing tree (which is given) should be scheduled to fire as efficiently as possible, while observing interference constraints (Two types commonly considered, primary and secondary. When demand for data is high relative to available bandwidth or time is limited, scheduling transmissions can be a difficult algorithmic problem. Optimization objectives here



include minimizing the delivery time for all data or maximizing total data delivered before a deadline. One-shot converge cast applies in urgent situations, when a one-time query for data is sent to the sensor network. Each sensor reports a single reading that must be scheduled for delivery to the sink, prior to some deadline. Interference constraints and bandwidth limitations may prevent all data items from being delivered on time. The goal in one-shot throughput maximization is to find a schedule delivering on time as many data items as possible (or more generally a maximum-weight set).If sensors continuously report data over time, and then a periodic schedule is appropriate. Following an initialization period in which the sensors' first data items are delivered, data items will have been received from all sensors. Therefore the natural goal is to minimize the latency of the items sent, and hence maximize throughput. This yields the problem of finding a minimum-length periodic schedule (in which every required transmission fires once). Because of the repetitive nature of a periodic schedule, it is standard to assume that edges on a path may fire out of order, since data can be pipelined between rounds of the schedule. This justification does not apply to one-shot scheduling, where an item's sequence of edge firings towards the sink must occur in consistent order.

### Aggregated Data Converge cast:

Converge cast in wireless sensor networks (WSN) typically refers to the many-to-one communication pattern, where data from a set of sources are routed toward a common sink. Often, many WSN applications [8], [14] require periodic summaries or aggregates of these data rather than raw sensor readings, in addition to quick delivery with minimum energy consumption. In such cases, data coming from different sources can be aggregated at each hope-route to the sink - eliminating redundancy, minimizing the number of transmissions, and thereby saving energy and improving network throughput. In this paper, we consider the converge cast process where aggregated data are periodically streamed from a set of sources to a common sink over a tree-based routing topology, and refer to it as aggregated converge cast. It is well known that contention-free medium access control (MAC) protocols like TDMA (Time Division Multiple Access) offer better solutions for such periodic data collection by eliminating collisions and retransmissions as opposed to contention based protocols. We therefore consider TDMA protocols where time slots are grouped into equal sized repeated frames. We call the number of time slots in each frame the schedule length, and assume that each node is scheduled to transmit in only one slot per frame, sending its own as well as aggregated data from its children. We also assume that the duration of each slot allows transmission for exactly one packet. Thus, once a pipeline is established, the sink will start receiving aggregated data from all the nodes in the network once in each frame. In this paper, we focus on the problem of minimizing the schedule length which, under this framework, is equivalent to maximizing the data collection rate at the sink. A natural approach to avoid interference and increase throughput in wireless networks is to use multiple frequency channels. While there is a lot of research on single-channel scheduling protocol design for WSN, exploiting parallelism using multiple channels has not yet been well explored. Given the fact that current WSN hardware already provides multiple frequencies, such as the 16 orthogonal frequencies with 5MHz spacing supported by CC2420 radios on Trotsky, it is imperative to take their full advantage in order to minimize interference and collisions - the two most predominant causes of packet losses - and thereby achieve faster data collection rate by parallel transmissions. In this work, we thus exploit the benefits of utilizing multiple frequencies

## Multi-Channel Scheduling for Fast Converge cast in Wireless Sensor Networks:

Converge cast, namely collection of data from sensors towards a common sink node over a tree topology is a fundamental operation in wireless sensor networks (WSN). In many applications, it is important to deliver the data to the sink in a limited amount of time and increase the speed of data collection at which the sink can receive data from the network. For instance in Lites [2], which is a real time monitoring application, a typical event may generate up to 100 packets within a few seconds and the packets need to be transported from different network locations to a sink node. Since the data has to be delivered in a short time, we consider time division multiple access (TDMA) [3] as a natural solution due to the collision free behavior. Consider a schedule of t time slots where the sink receives data from all nodes in the network once every t slots. In such a context, the objective is to minimize t to increase the speed of data collection. We study a set of techniques in order to solve the fundamental problem: “how fast can data be converge cast to the sink over a tree topology?” The fundamental limiting factors are interference and half-duplex nature of the transceivers on WSN nodes. To cope with interference we consider different techniques such as transmission power control and assigning different frequency channels on interfering links. We show that once multiple frequencies are employed with spatial-reuse TDMA, the converge cast schedule becomes limited by the number of nodes in the network once a suitable routing tree is used. For further improvements, we consider equipping a single sink with multiple transceivers, and also the deployment of multiple sinks to collect data. We evaluate the above mentioned techniques using mathematical analysis and simulations that use realistic channel models and radio parameters typical of WSN radio devices. The following are some of the findings and key contributions of this work:

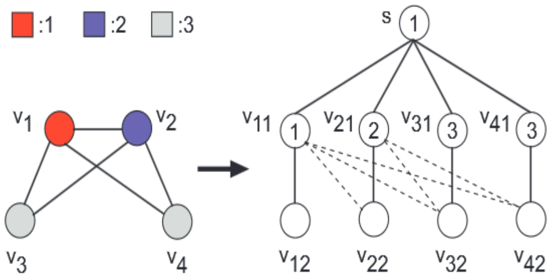
- Evaluation of transmission power control to eliminate interference: Under idealized settings (unlimited power, continuous range) power control mechanisms may provide unbounded improvements in the speed of data collection. We evaluate the behavior with an optimal power control algorithm described in [4] in a practical setting considering the limited discrete power levels available in today’s radios on WSN nodes.

- Receiver-based frequency assignment: We show that scheduling transmissions on different frequency channels is more efficient in mitigating the effects of interference compared with transmission power control. Accordingly, we define a receiver-based channel assignment problem which is “the problem of assigning a minimum number of frequencies to the receivers such that all the interference links in an arbitrary network is removed”. We show that the problem is NP-complete and introduce a greedy heuristic for channel assignment. By simulations and analytical calculations, we evaluate the behavior of our heuristic algorithm and compare its performance with another channel assignment method which was recently proposed for WSN with tree topologies.

- Bounds on converge cast scheduling: We show that, once the interference is eliminated, the achievable schedule length with half-duplex transceivers is bounded by max(2nk−1, N)slots where nk is the maximum number of nodes on any branch of the tree and N is the number of nodes. We modify an existing time slot assignment algorithm and show that the algorithm requires exactly max (2nk−1, N) slots to schedule a given network.

- Impact of Routing Trees: According to the bound on converge cast schedules, the branches of a routing tree should have balanced number of nodes such that 2nk−1< N. Such a tree construction is defined as the “Capacitated Minimal Spanning Tree Problem” and is proved to be NP-completes. Given the hardness of the problem, we propose a heuristic algorithm and evaluate the impact of such routing trees on the schedule length by simulations.

- Multiple transceivers at the sink node: For further improvements we consider the sink having multiple transceivers and multiple sinks deployed in the network. We observe improved reductions on the schedule length that are proportional with the number of available transceivers. The remainder of the paper is organized as follows: in Section II, we introduce the problem. In Section III we explain the mechanisms that we use to eliminate interference. In Section IV, we introduce a receiver-based greedy channel assignment algorithm. In Section V, we provide the bounds on the converge cast schedule when interference is eliminated and present a modified time slot assignment algorithm that achieves the lower bound. In Section VI, we discuss the impact of routing trees on the generated schedules. Section VII gives the detailed simulation based evaluation of the discussed methods. Section VIII summarizes some of the related work. Finally, Section IX provides the concluding remarks.



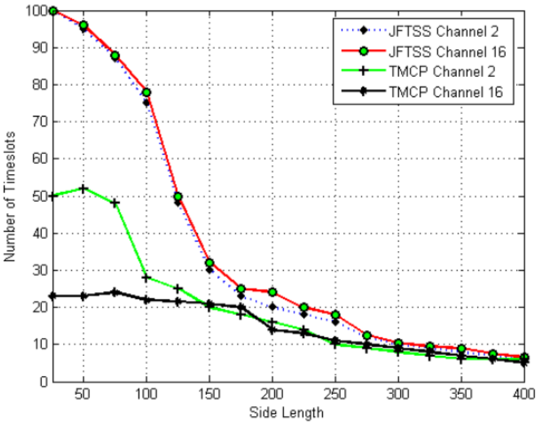
Reduction from vertex color

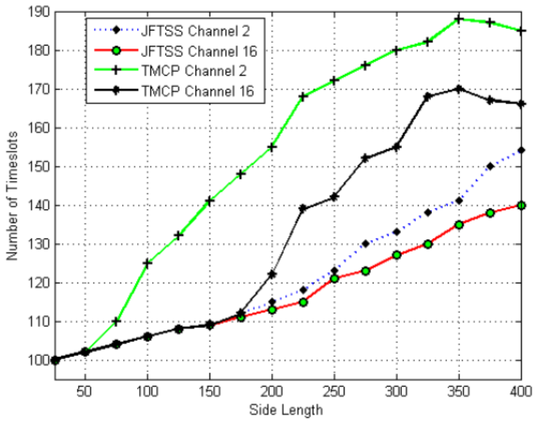
The rules associated to the algorithm are:

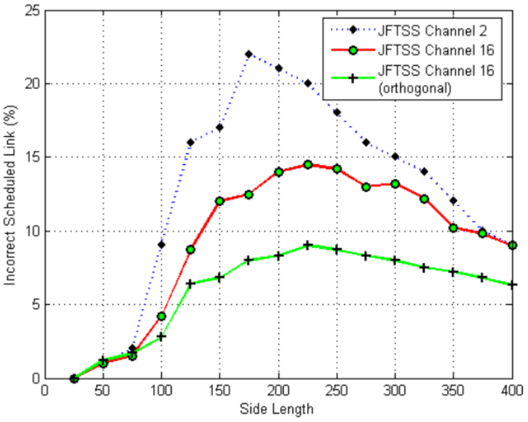
Rule 1. Nodes having single parents are connected first.

Rule 2. Nodes with multiple parents, a Reservoir Set (RS) are created and select one from it. Rule 3. After selecting a node from RS a search set S is constructed to decide which particular branch the node should be added to. S therefore consist of nodes that are not yet connected but are neighbors of a node with high hop-count

**Performance Evaluation:** In this section, we evaluate performance of multiple channels and network tree topology on scheduling for both aggregated and raw-data converge cast. We deploy sensor nodes randomly in a region with dimensions varying between 30x30 m 2 and 400x400 m 2 to have different network density. The number of nodes is fixed to 100 and for different parameters; we average each point over 1500 runs. An exponential path-loss model for signal propagation along-with the path-loss exponent varying between 3 and 4 is used. We have simulated the behavior of CC2420 radios used on Trotsky motes and are able to operate on 16 different frequencies. The transmission power can be adjusted between -24 and 0 dBm over eight different levels and the SINR threshold is set to β = -3dB. Firstly, the schedule length of single-channel TDMA is determined, secondly its improvement using multiple channels and routing trees is evaluated. All the nodes transmit at maximum power and uses minimum hop tree. In TMCP time slots are assigned according to Algorithm 1 for raw data converge cast and Algorithm 2 for aggregated converge cast. The path loss exponent is 3.5. The results are shown in Fig. 5(a) and 5(b). It is evident from Fig. 5(a) that with just two frequencies interference limitations are eliminated and the performance gains are limited by the connectivity structure. With multichannel communication a 40 percent reduction in schedule length is observed as compared to transmitting on a single channel with maximum power. Further, JFTSS can optimally schedule the network using 16 channels as shown in graph of Fig. 5. In dense deployments, TMCP performs better due to construction of different routing trees i.e., when L = 20, JFTSS construct a star topology, whereas TMCP constructs a 2-branch tree with two channels and a 16-branch tree with 16 channels







**Impact of Interference:**

Multi-hop wireless networks have been studied since the 70's [6]. Several new applications of such networks have recently emerged. Community wireless networks [1, 3] are multi-hop wireless networks that provide \last-mile" access to peoples' homes. This approach is an alternative to cable modem and DSL technologies. In large networks of sensors [10] the scale and the environment are such that a multi-hop wireless network is the only feasible means of communication. A fundamental issue in multi-hop wireless networks is that performance degrades sharply as the number of hops traversed increases. For example, in a network of nodes with identical and unidirectional radio ranges, going from a single hop to 2 hops halves the throughput of a tow because wireless interference dictates that only one of the 2 hops can be active at a time. The performance challenges of multi-hop networks have long been recognized and have led to a lot of research on the medium access control (MAC), routing, and transport layers of the networking stack. In recent years, there has also been a focus on the fundamental question of what the optimal capacity of a multi-hop wireless network is. The seminal paper by Gupta and Kumar [16] showed that in a network comprising of n identical nodes, each of which is communicating with another node, the throughput capacity per node is ( 1 pn log n) assuming random node placement and communication pattern and ( 1 pn) assuming optimal node placement and communication pattern. Subsequent work has considered alternative models and settings, such as the presence of relay nodes and mobile nodes, and locality in inter-node communication, and their results are less pessimistic [13, 20, 12]. This paper also deals with the problem of computing the optimal throughput of a wireless network. However, a key distinction of our work from previous work such as [16] is that we work with any given wireless network conjuration and workload specie as inputs. In other words, the node locations, ranges, etc. as well as the trace matrix indicating which source nodes are communicating with which sink nodes are specie as the input. We make no assumptions about the homogeneity of nodes with regard to radio range or other characteristics, or regularity in communication pattern. This is in contrast to previous work that has focused on asymptotic bounds under assumptions such as node homogeneity and random communication patterns. We use a contact graph to model the effects of wireless interference. The con it graph indicates which groups of links mutually interfere and hence cannot be active simultaneously. We formulate a multi-commodity. w problem [8], augmented with constraints derived from the consist graph, to compute the optimal throughput that the wireless network can support between the sources and the sinks. We show that the problem of ending optimal throughput is NPhard, and we present methods for computing upper and lower bounds on the optimal throughput. We show how our methodology can accommodate a diversity of wireless network characteristics such as the availability of multiple non overlapping channels, multiple radios per node, and directional antennae. We also show how multiple MAC protocol models as well as single-path and multi-path routing constraints can be accommodated. We view the generality of our methodology and the convict graph framework as a key contribution of our work. To compute bounds on the optimal throughput, we assume that packet transmissions at the individual nodes can be only controlled and carefully scheduled by an omniscient and omnipotent central entity. While this is clearly an unrealistic assumption, it gives us a best case bound against which to compare practical algorithms for routing, medium access control, and packet scheduling. Moreover, ns-2 simulations show that the routes derived from our analysis often yield noticeably better throughput than the default shortest path routes, even in the presence of real-world e acts such as uncoordinated packet transmissions and MAC contention. In some cases, the throughput gain is over a factor of 2. The reason for this improvement is that in optimizing throughput, we tend to and routes that are less prone to wireless interference. For instance, a longer route along the periphery of the network may be picked instead of a shorter but more interference prone route through the middle of the network. We use our technique to evaluate how the per-node through put in a multi-hope wireless network varies as the number of nodes grows. Previous work (e.g., [16]) suggests that the per-node throughput falls as the number of nodes grows. But this result is under the assumption that nodes always have data to send and are ready to transmit as fast as their wireless connection will allow. In a realistic setting, however, sources tend to be bursty, so nodes will on average transmit at a slower rate than the speed of their wireless link. In such a setting, we and that the addition of new nodes can actually improve the per-node throughput because the richer connectivity provides increased opportunities for routing around interference \hotspots" in the network. This more than o sets the increase in trace load caused by the new node. The rest of this paper is organized as follows. In Section 2, we discuss related work. In Section 3, we present details of our consist graph model and methods for computing bounds on the optimal network throughput. In Section 4, we present results obtained from applying our model to deferent network and workload conjurations. Section 5 concludes the paper.

**Computing Bounds On Optimal Throughput:** We now present our framework for incorporating the constraints imposed by interference in a multi-hop wireless network and then present methods for computing bounds on the optimal throughput that a give network can support for a given trace workload. We begin with some background and terminology.

**Multipath Routing under the Protocol Interference Model :** Given a wireless network with N nodes, wrest derive connectivity graph C as follows. The vertices of C correspond to the wireless nodes (NC) and the edges correspond to the wireless links (LC) between the nodes. There is a directed link lij from node ni to nj if dij Ri and i 6= j. We use the terms \node" and \link" in reference to the connectivity graph while reserving the terms \vertex" and \edge" for the convict graph presented. Let us rst consider communication between a single source, and a single destination. In the absence of wireless interference (e.g., on a wired network), ending the maximum achievable tow between the source and the destination, given the edibility of using multiple paths, can be formulated as a linear program corresponding to a meow problem, in. Here, fij denotes the amount of tow on link lij , Cape denote the capacity of link lij, and LC is a set of all links in the connectivity graph.

### Evaluation:

Wireless mesh networks allows outdoor environments to be interconnected without any wires and with the security and reliability of a wired network. They solve a wide range of communications challenges across different outdoor environments, making them well suited for public safety, emergency response, oil rigs, video surveillance, large scale events and transportation hubs. An all-wireless network mesh brings the convenience of easy installation and lower deployment costs. Wireless mesh networks must meet the same standards for scalable capacity, reliability and security as do their wireless LAN (WLAN) counterparts. Issues with throughput, quality and security in a wireless mesh network have largely been resolved, but scalable capacity remains an obstacle with some vendor solutions. Many wireless mesh solutions simply cannot scale without compromising performance, quality of service (QoS) or availability across multiple hops in a mesh infrastructure. And in always-on, mission-critical communications environments, that’s simply not acceptable. The scalable capacity challenge is rooted in the nature of wireless networking. The inherent inefficiencies of sharing the radio frequency (RF) spectrum are a primary contributor to scalability issues. A second cause is Layer 2 switching or bridging. The design of the link-layer wireless protocols used in switching or bridging have adverse consequences for wireless mesh scalability, flexibility and performance. Wired Ethernet has resolved the scalable capacity challenge. First, significantly greater bandwidth is available with wired networks than with wireless, so the impact is smaller. And second, wired Ethernet uses IP routing. The shared nature of RF means that the available bandwidth on a wireless network will be less than on a wired network, but the scalable capacity challenge can be met by using true network-layer routing on the wireless mesh network. Until now, true network-layer routing has been considered too complex and costly to be practical. But Aruba Networks has made a significant investment in its adaptive Layer 3 wireless mesh routing protocol to advance the state-of-the-art networking in three significant ways:

- Network-layer routing. Aruba provides efficient network-layer routing that is designed specifically for the wireless mesh. With network-layer routing, wireless mesh networks can deliver the scalability, throughput and low-latency across multiple mesh hops and over large geographic areas to meet the demands of delay-sensitive applications.

- High-speed mobility. Aruba's high-speed roaming capabilities – both within a single IP domain and across multiple domains – integrate IP routing with wireless link-level access to support seamless roaming.

- Support for high-quality voice and video. Aruba's innovative traffic-shaping technology ensures the delivery of high-definition video and high-quality voice by enforcing QoS and bandwidth management.

## Conclusions:

In this paper, we studied quick converge cast in WSN where nodes communicate using a TDMA protocol to minimize the schedule length. We addressed the fundamental limitations due to interference and half-duplex transceivers on the nodes and explored techniques to overcome the same. We found that while transmission power control helps in reducing the schedule length, multiple channels are more effective. We also observed that node-based (RBCA) and link-based (JFTSS) channel assignment schemes are more efficient in terms of eliminating interference as compared to assigning different channels on different branches of the tree (TMCP). Once interference is completely eliminated, we proved that with half-duplex radios the achievable schedule length is lower bounds are achievable once a suitable routing scheme is used. Through extensive simulations, we demonstrated up to an order of magnitude reduction in the schedule length for aggregated, and a 50% reduction for raw-data converge cast. In future, we will explore scenarios with variable amounts of data and implement and evaluate the combination of the schemes considered

## References

1. C. Papadimitriou, "The complexity of the capacitated tree problem,"Networks , vol. 8, no. 3, pp. 217–230, 1978..

2. J. Gr ¨onkvist and A. Hansson, "Comparison between graph-based and interference-based stdma scheduling," in MobiHoc '01 , Long Beach, CA, USA, pp. 255–258.

3. W. Song, F. Yuan, and R. LaHusen, "Time-optimum packet scheduling for many-to-one routing in wireless sensor networks," in MASS '06, pp. 81–90.

4. H. Choi, J. Wang, and E. Hughes, "Scheduling for information gathering on sensor network," Wireless Networks (Online), 2007.

5. N. Lai, C.King, and C. Lin, "On maximizing the throughput of

convergecast in wireless sensor networks," in GPC '08 , pp. 396–408.

6. M. Pan and Y. Tseng, "Quick convergecast in zigbee beacon enabled tree-based wireless sensor networks," Computer Communications, vol. 31, no. 5, pp. 999–1011, 2008.
7. W.-Z. Song, R. Huang, B. Shirazi, and R. LaHusen, "Treemac: Localized tdma mac protocol for real-time high-data-rate sensor networks," Pervasive Mob. Comput. 5, no. 6, pp. 750–765, 2009.
8. G. Zhou, C. Huang, T. Yan, T. He, J. Stankovic, and T. Abdelzaher, "Mmsn: Multi-frequency media access control for wireless sensor networks," in INFOCOM '06, pp. 1–13.
9. Y. Kim, H. Shin, and H. Cha, "Y-mac: An energy-efficient multi channel mac protocol for dense wireless sensor networks," in IPSN '08 , April 2008, pp. 53–63.
10. B. Krishnamachari, D. Estrin, and S. Wicker, "The impact of data aggregation in sensor networks," in ICDCSW '02 , pp. 575–578.
11. J. Zander, "Performance of optimum transmitter power control in cellular radio systems," IEEE Transactions on Vehicular Technology, vol. 41, no. 1, pp. 57–62, 1992
12. S. Upadhyayula and S. Gupta, "Spanning tree based algorithms for low latency and energy efficient data aggregation enhanced convergecast (dac) in wireless sensor networks," Ad Hoc Networks ,vol. 5, no. 5, pp. 626–648, 2007.
13. T. Moscibroda, "The worst-case capacity of wireless sensor networks," inIPSN '07, Cambridge, MA, USA, pp. 1–10.
14. T. ElBatt and A. Ephremides, "Joint scheduling and power control for wireless ad-hoc networks," in INFOCOM '02, Jun, pp. 976–984.
15. O. D. Incel and B. Krishnamachari, "Enhancing the data collection rate of tree-based aggregation in wireless sensor networks," in SECON '08, San Francisco, CA, USA, pp. 569–577.
16. Y. Wu, J. Stankovic, T. He, and S. Lin, "Realistic and efficient multi-channel communications in wireless sensor networks," in INFOCOM '08, pp. 1193–1201.
17. A. Ghosh, O. D. Incel, V. A. Kumar, and B. Krishnamachari,"Multi-channel scheduling algorithms for fast aggregated convergecast in sensor networks," in MASS '09, Macau, China.

**Bibliography:**

G.V.S.krishnapriya, M.Tech Degree in Computer Science Engineering, Aditya Engineering college, Kakinada, India. Done this project with reference to Rama Sree Madam, with own interest.

**Mrs. S. Rama Sree** obtained her B.Tech. Degree in Computer Science & Engineering from Koneru Lakshmaiah College of Engineering, affiliated to Jawaharlal Nehru Technological University Kakinada and M.Tech Degree in Computer Science from Jawaharlal Nehru Technological University Kakinada, India. She is currently a Research Scholar and working as professor and Head of the Department of Computer Science & Engineering at Aditya Engineering college, Surampalem, India. She has 18 international Journal Papers and 5 National/ International Conferences to her credit. Her research interests include Software Engineering, Cost Estimation, Fuzzy Logic, Neural Networks and Neuro Fuzzy Systems.