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Mitigating Congestion in High Speed Wireless Multimedia Sensor Networks Using Energy Efficient Grid Based D^3 Technique

Mantoj Kaur, Malti Rani
Punjab Institute of Technology, Kapurthala, Punjab

Tulika Mehta
UIET Panjab University, Chandigarh
India

ABSTRACT

In high speed wireless multimedia sensor networks (WMSNs) a sensor node have different types of sensor node which gather different types of data. In such high speed event driven network, it is critical to report the detected immediately which results in bursts of traffic that causes congestion and packet loses in such networks. Various congestion control techniques usually detect congestion and then recover the network, but do not avoid congestion. In this paper, we present an energy efficient grid based D^3 (Dynamic Data Dissemination) technique which avoids/controls congestion to occur in network. It uses queue buffer length to estimate congestion and then dynamically disseminates data to multiple forwarders. To make the technique energy efficient, we deploy the sensor node in grid based strategy that improves energy efficiency, packet delivery ratio and throughput.

Keywords:- Wireless Multimedia Networks, Congestion Avoidance, Energy Efficiency, Grid Based Technique.

I. INTRODUCTION

Wireless sensor network is collection of sensor nodes which senses the network for any change or any event to occur. It consists of one or more sinks which gathers the sensed information from sensor nodes and large number of sensor nodes scattered in an area. With the integration of information sensing, computation, and wireless communication, sensor nodes can sense the physical phenomenon, or pre-process the "raw" information, share the processed information with neighbouring nodes, and report information to the sink [1]. A wireless multimedia sensor network (WMSN) is a set of sensor nodes which are equipped with multimedia devices such as cameras and microphones. They have capability to transmit pictures, videos, sounds etc. WMSN supports different types of traffic classes such as loss tolerant, time critical etc. Like Wireless sensor nodes, WMSN also generates streaming data directed towards sink in multi-hop manner which may lead to congestion in some cases. High speed upstream traffic is prone to cause congestion which will impair QOS of multimedia applications in WMSNs [2].

Some nodes may be constantly generating streaming of data must be directed in a multi-hop manner to the sink node. A large number of generated packets with variable wireless network conditions may result in unpredictable traffic load and congestion to area near the sink. The main objective of this study is to design a robust energy efficient congestion avoidance/control technique.
The paper is organized in the given manner: Section 1 contains the introduction about the wireless multimedia sensor network and congestion in these networks. Section 2 describes the related work done to control the congestion. Section 3 compares the related protocols and section 4 contains the proposed work followed by conclusion in section 5.

II. RELATED WORK

Congestion is basically of two types: Node-level congestion, Link-level congestion. Node-level congestion is caused by buffer overflow in the node and can result in packet loss, and increased queuing delay. Packet loss in turn can lead to retransmission and therefore consumes additional energy. Link-level congestion increases packet service time, and decreases both link utilization and overall throughput, and wastes energy at the sensor nodes. Both node-level and link-level congestions have direct impact on energy efficiency and QoS [3].

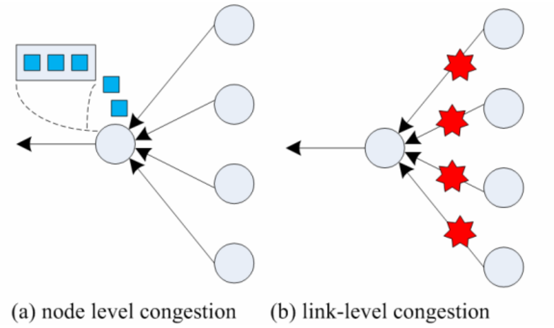

Figure 1: Types of Congestion

There are several transport protocols that have been designed for wireless sensor networks. A list of relevant related works on transport protocol wireless sensor network is given in Figure 2. The existing transport protocols are distinguished by three different categories which are reliability for upstream and downstream, congestion control and protocol that provides both reliability and congestion control.

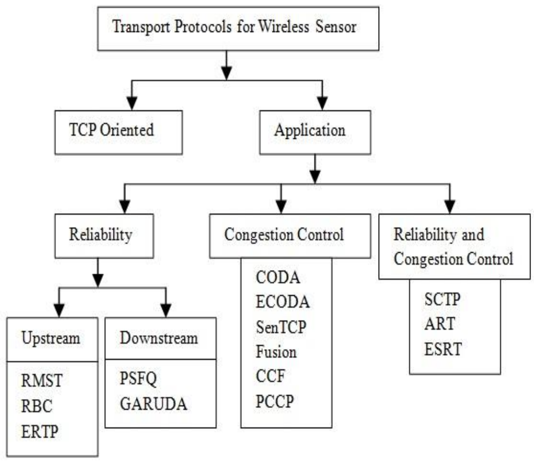

Figure 2: Existing Protocols in WSN

Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are two traditional transport protocols that are currently used for the internet. TCP is a reliable end-to-end transport protocol which is widely used for data services and very efficient for wired networks. The basic idea of TCP congestion control is that TCP waits for available resources then send data and increase the transmission rate until packet losses are detected [4]. However, TCP cannot be directly implemented and may not be suitable for data transport in WSNs due to specific characteristics and requirements of WSN.

The transport protocols that provide only reliability are: Pump Slowly and Fetch Quickly (PSFQ) [5] and GARUDA [6] is a reliable communication from sink to sensor nodes (downstream). PSFQ is designed to be scalable and energy efficient, trying to minimize the number of signalling messages and relying on multiple local timers. While GARUDA solves the problem of reliable transport by transmitting a high energy pulse, called WFP (Wait for First Packet) before transmitting the first packet. However, both of these downstream protocols do not provide any congestion control scheme.

There are three transport protocols that provide reliability for upstream direction which are Reliable Multi-segment Transport Protocol (RMST) [7], Reliable Bursty Converge-cast (RBC) [8] and Energy Efficient and Reliable Transport Protocol (ERTP) [9]. RMST adopts a cross layer between network layer and MAC layer in order to guarantee hop-by-hop reliability. It is also designed to run Directed diffusion (to use its discovered path from sensors to sink) in order to provide guaranteed reliability from sensors to sink (delivery and fragmentation/reassembly) for applications [10]. The aim of RBC protocol is to improve channel utilization. It guarantees continuous packet forwarding and replicates the acknowledgement for packet. While ERTP is designed for data streaming that ensure reliable delivery of sensor data packets delivered to the sink. This protocol provides both transmission reliability and energy efficient. ERTP uses Stop and Wait Hop-by-Hop Implicit Acknowledgement for loss recovery. For energy efficient, ERTP control the reliability at each hop to achieve end-to-end reliability.

In figure 2, there are six transport protocols that provides only congestion control mechanism which are Congestion Detection and Avoidance (CODA), Enhanced Congestion Detection and Avoidance (ECODA), SenTCP, Fusion, Congestion Control and Fairness (CCF) and Priority-based Congestion Control Protocol (PCCP). But, all of these protocols do not have any reliability mechanism. The Congestion Detection and Avoidance (CODA) as described in [11] proposed energy efficient congestion control three schemes, which are congestion detection, open loop hop-by-hop backpressure and end-to-end multi-source regulation. CODA senses congestion by taking a look at each sensor node's buffer occupancy and wireless sensor load. Enhanced congestion detection and avoidance (ECODA) [12] uses dual buffer thresholds and weighted buffer difference for congestion detection and adopts hop-by-hop congestion control scheme for transient congestion. In [13], SenTCP is an open loop hop-by-hop congestion control protocol for upstream traffic flow. SenTCP calculates the congestion degree in every intermediate sensor node by using packet arrival time and packet inter-arrival time. The uses of hop-by-hop feedback control regulate the congestion quickly and reduce packet dropping, which in turn conserve energy and increases the throughput. The Fusion protocol as described in [14] provides congestion control and fairness. Each sensor node performs congestion detection based on measurement of packet queue length. Congestion notification (CN) bit will set in the header of every outgoing packet when the node detects congestion. Once the CN bit is set, neighboring node can overhear it and stop forwarding packet to the congested node. Congestion Control and Fairness (CCF) [15] and Priority-based Congestion Control Protocol (PCCP) [16] are provides congestion control and fairness. CCF detects congestion based on packet service time at MAC layer and control congestion based on hop-by-hop manner with simple fairness. CCF uses packets service time to deduce the available service rate and detect the congestion in each intermediate node. When the congestion is experienced, it informs the downstream nodes to reduce their data transmission rate and vice versa. While PCCP calculates a congestion degree as the ratio of packet inter-arrival time and packet service time which is used to achieve exact rate adjustment with priority-based fairness. PCCP uses implicit congestion notification by piggybacking the congestion information in the header of data packets.

There are three protocols that provides both reliability and congestion control which are Event to sink Transport Protocol (ESRT), Sensor Transmission Control Protocol (STCP) and Asymmetric and Reliable Transport (ART). Event-to-sink reliable transport (ESRT) [17] protocol is a novel transport developed to achieve reliable event detection in WSN with minimum energy expenditure. The goal of ESRT is to adjust the reporting frequency of source nodes in order to achieve the end-to-end desired reliability. But, ESRT assume that the base station is one-hop away from all sensor nodes. Sensor Transmission Control Protocol (STCP) [18] is a generic, scalable and reliable transport layer protocol where a majority of the processes are done at the base station. STCP offers controlled variable reliability, congestion detection and avoidance, and supports multiple applications in the same network. STCP assumes that all the sensor nodes within the WSN have clock synchronization. In [19], ART have three main functions which are reliable query transfer, event transfer and distributed congestion control. ART selects a subset of sensor nodes called essential node (E-nodes) and nonessential node (N-nodes) that can cover the whole area to be sensed in an energy efficient way. When there is no congestion, both E-node and N-node are participating in relaying message to the sink.

There are four other improved congestion control protocols, which are: Queue-based congestion control protocol with priority support (QCCP-PS) [21], Fairness-aware congestion control (FACC) [22], Prioritized heterogeneous traffic-oriented congestion control protocol (PHTCCP) [23], Tunable reliability with congestion control for information transport (TRCCIT)[24]. QCCP-PS is a queue based Congestion Control Protocol with Priority Support which uses the queue length as a congestion degree indicator. The sending rate of each traffic source in the QCCP-PS is increased or decreased based on its congestion degree and its priority index. FACC protocol is a rate-based protocol dividing intermediate nodes into near-source and near-sink based on the application and QoS requirements. PHTCCP uses traffic priority based MAC protocol (differentiating inter-frame-spacing and back-off mechanisms) by assigning short IFS and back-off to the higher priority traffic. PHTCCP use packet service ratio as congestion indication.

III. PROTOCOL COMPARISON

This section compares the existing protocols on the basis of energy efficiency, congestion control and reliable message delivery. Table 1 shows the comparison between existing protocols on the basis of reliability and energy efficiency. Reliability is a main objective in transport layer which guarantees the packet delivery from source to sink node. Table 2 shows the congestion control mechanisms which have congestion detection (queue length, packet service time, packet inter-arrival time etc.), congestion notification (Implicit and Explicit notification) and congestion avoidance (Stop and start, AIMD, rate adjustment) that are differently supported by different protocols.

Table 1 Reliability and Energy Efficient Comparison

Protocol	Reliability										Energy Efficient
				Loss Detection and Notification					Loss recovery		
	Category	Direction	Type	ACK	NACK	IACK	Sequence number out of order	Time Out	Increase Source sensing rate	Packet Retransmission	
RMST	Packet	Upstream	Hop-by-hop		√			√		√	Good
RBC	Packet	Upstream	Hop-by-hop		√	√					No
ERTP	Packet	Upstream	End-to-end			√		√		√	Good
PSFQ	Packet	Downstream	Hop-by-hop		√		√	√		√	No
GARUDA	Packet	Downstream	Hop-by-hop		√		√			√	No
CODA	Event		Hop-by-hop								Good
ECODA	Periodic		Hop-by-hop								
SenTCP	Event/ Periodic		Hop-by-hop								Good
Fusion	Hybrid		Hop-by-hop								No
CCF	Event		Hop-by-hop								No
PCCP	Event/ Continuous		Hop-by-hop								No
ESRT	Event	Upstream	Event-to-sink					√	√		Fair
STCP	Event/ Packet	Upstream	End-to-end	√	√			√		√	No
ART	Event/ Query	Both	End-to-end	√	√			√		√	No
QCCP-PS	Multimedia		Hop-by-hop								No
FACC	Continuous		Hop-by-hop								No
PHTCCP	Periodic		Hop-by-hop								No
TRCCIT	Packet		Hop-by-hop								No

Table 2 Congestion Control Comparison

Protocol	Congestion Control										Energy Efficient
	Congestion Detection					Congestion Notification		Congestion Control			
	Packet Sending Success	Queue Length	Service Time	Service time/ Inter-arrival time	Channel Loading	Explicit	Implicit	Stop and Start	Additive increase Multiplicative decrease	Exact Rate Adjustment	
RMST	Hop-by-hop										Good
RBC	Hop-by-hop	Remaining queue length					√	Stop Sending			No
ERTP	End-to-end										Good
PSFQ	Hop-by-hop										No
GARUDA	Hop-by-hop										No
CODA	Hop-by-hop	√			√	√			√		Good
ECODA	Hop-by-hop	√					√			√	
SenTCP	Hop-by-hop	√		√		√					Good
Fusion	Hop-by-hop	√					√	√			No
CCF	Hop-by-hop	√	√				√			√	No
PCCP	Hop-by-hop			√			√			√	No
ESRT	Event-to-sink	√					√			√	Fair
STCP	End-to-end	√					√		√		No
ART	End-to-end		√				√	Stop Sending			No
QCCP-PS	Hop-by-hop	√					√			√	No
FACC	Hop-by-hop	√			√	√				√	No
PHTCCP	Hop-by-hop			√			√			√	No
TRCCIT	Hop-by-hop		√				√			√	No

IV. PROPOSED WORK

In Wireless sensor Networks (WSN), Congestion control techniques detect congestion and attempt to recover from packet losses due to congestion, but they cannot eliminate or prevent the occurrence of congestion. But proposed method is based on Congestion avoidance technique, that instead of reducing the traffic rate to control the congestion, distribute the data traffic through the other nodes to achieve good throughput. Hence this Congestion avoidance technique uses the queue buffer length of the sensor nodes to estimate the congestion and disseminate traffic to provide a congestion-free routing path is preferred in WSN [25].

Congestion is detected in the network when the sensor node's queue overflows and packets start to drop. The node is said to be congested and cannot handle any further packets until its buffer starts to clear. When a node 'i' has a data packet to transmit, it computes the virtual queue length for all its forwarder set nodes, based on the number of packets in node i's queue, the number of packets in the neighbor's queue, and the number of packets dropped by node 'i' due to an excessive number of retransmissions after the most successful transmission. This proposed protocol does not use any additional control messages, it has to maintain multiple queues and compute the virtual queue length for all forwarders for each data packet. The main objective of this work is to avoid control messages and unwanted computation that will degrade the network performance. This will make the proposed D^3 technique light weight and more efficient [25]. The forwarders are set up as shown in figure 3:

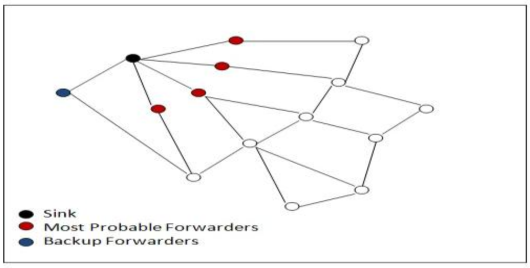

Figure 3: Dynamic Data Dissemination Technique

Most Probable forwarders - The D^3 technique addresses the difficulty faced with a single forwarder by adopting multiple probable forwarders for each node.

Backup forwarder - A backup node is used only when none of the probable forwarders are available for data transmission.

The proposed method uses differentiated services to further alleviating congestion in WMSNs by ensuring that the data leaving each and every node in the network gets prioritized differential treatment. This method assumes that data originating from the WMSN can be mapped to the following traffic classes [25].

Real-time Loss In tolerant Data: Time and mission critical data is mapped to this traffic class. Such data demands low delay and high reliability. Invariably, critical scalar data is short lived, therefore the mean bandwidth consumed by such data is small.

Real-time Loss Tolerant Data: Critical scalar data that requires low delay and low reliability is mapped to this traffic class. Dense sensor nodes deployment can be one reason that the data mapped to this traffic class is loss tolerant. If one reading is corrupted or dropped during the transmission, it is highly likely that the reading sent by a nearby sensor node will compensate for the lost reading.

Delay Tolerant and Loss In tolerant Data: Data that emerges in response to a query that does not involve mission critical aspects of the system is mapped to this traffic class.

Delay Tolerant and Loss Tolerant Data: Data that is neither mission critical nor time critical e.g., non-critical regular reporting data.

This proposed method deploy the sensor nodes in Grid based technique which divides a sensor field into grid squares and every sensor uses its location information, which can be provided by GPS to associate itself with a particular grid in which it resides. The size of the grid square is chosen in a way such that sensors within the same grid are equivalent with regard to routing and that sensors in adjacent grids can communicate with each other. Thus, equivalent sensors can coordinate with each other to determine energy–efficient schedule of their activities, which specifies when and for how long the sensors stay awake or sleep. To maximize the network lifetime each grid has only one active sensor based on sensor ranking rules. The ranking of sensors is based on their residual energy levels. Thus, a sensor with a higher rank will be able to handle routing within their corresponding grids [1]. The active and sleeping sensors in grid based deployment strategy are shown in figure 4.

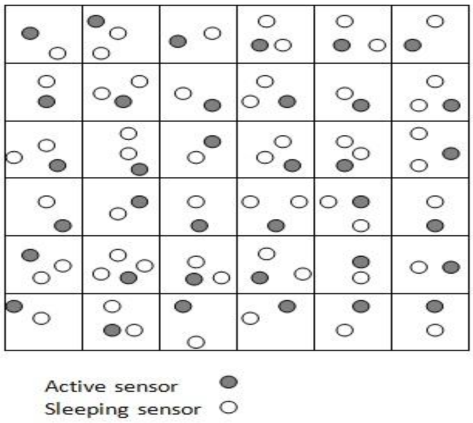

Figure 4: Grid Based Technique

V. CONCLUSION

In this paper, we had done comparative study of various existing transport layer protocols and proposed a new energy efficient grid based D^3 technique, which increase the network life time, packet delivery ratio and throughput. The existing protocols do not focus on energy efficiency parameter, but in proposed methodology, energy efficiency is main objective. In a grid, only one node is responsible for data transmission while others are in sleeping state. After passing through grid, data is transferred by multiple forwarders to avoid congestion which improves the packet delivery ratio and throughput of network.

REFERENCES

[1] J. Zheng, A. Jamalipour, *"Wireless Sensor Networks: A Networking Perspective"* in Institute of Electrical and Electronics Engineers, 2009.

[2] M. H. Yaghmaee, Donald A. Adjeroh, "*Priority-based rate control for service differentiation and congestion control in*

wireless multimedia sensor networks" in Elsevier Journal of Computer Networks, 2009, pp. 1798-1811.

[3] C. Wang, B. Li, K. Sohraby, M. Daneshmand, and Y. Hu, "*Upstream Congestion control in wireless sensor networks through cross-layer optimization*," IEEE Journal on Selected Areas in Communications, 2007, vol.25, no. 4, pp. 786–795.

[4] Y. M. Liu, X. H. Jiang, X. H. Nian and W. Y. Lu, "*Improved DCCP Congestion Control for Wireless Sensor Networks*," 8th IEEE/ACIS International Conference on Computer and Information Science, 2009.

[5] C. Wan, A. T. Campbell, L. Krishnamurthy, "*PSFQ: A Reliable Transport Protocol for Wireless Sensor Network*," 1st ACM International Workshop on Wireless sensor network and Application, 2002.

[6] S. J. Park, R. Vedantham, R. Sivakumar and I. F. Akyildiz, "*A Scalable Approach for Reliable Downstream Data Delivery in Wireless Sensor Network*," in Proceeding of ACM MobilHoc'04,2004.

[7] F. Stann and J. Heidemann, "*RMST: Reliable Data Transport in Sensor Networks,*" IEEE International Workshop on Sensor Net Protocol and Applications (SNPA), 2003.

[8] H. Zhang, A. Arora, Y. Choi, and M. G. Gouda, "*Reliable Bursty Convergecast in Wireless Sensor Networks*," in Proceeding ACM MOBIHOC'05,2005.

[9] T. Le, W. Hu, P. Corke and S. Jha, "*ERTP:Energy-efficient and Reliable Transport protocol for Data Streaming in Wireless Sensor Networks*," Journal of Computer Communication 32 (2009), 2009, pp. 1154-1171.

[10] K. Akkay, M. Younis, "*A survey on Routing Protocol for Wireless Sensor networks*," Ad Hoc Networks 3, November 2003.

[11] C. Y. Wan, S. B. Eisenman and A. T, Campbell, "*CODA: Congestion Detection and Avoidance in Sensor Networks,*" in proceedings of ACM Sensys'03, 2003.

[12] L. Q. Tao and F. Q. Yu, "*ECODA: Enhanced Congestion Detection and Avoidance for Multiple Class of Traffic in Sensor Networks*," IEEE Transactions on Consumer Electronics, Vol. 56, No. 3, 2010, pp.1387-1394.

[13] C. Wang, K. Sohraby, and B. Li, "*SenTCP: A hop-by-hop Congestion Control Protocol for Wireless Sensor Networks,*" in Proceeding of IEEE INFOCOM, 2005.

[14] B. Hull, K. Jamiieson and H. Balakrishna, "*Mitigating Congestion in Wireless Sensor Networks*" in Proceedings ACM Sensys'04, 2004.

[15] C. T. Ee and R. Bajcsy, "*Congestion Control and Fairness for Many-to-One routing in Sensor Networks,*" in Proceeding ACM Sensys'04, 2004.

[16] C. Wang, K. Sohraby, V. Lawrence, B. Li and Y. Hu, "*Priority-based Congestion Control in Wireless Sensor Networks*," in Proceeding of IEEE International Conference on Sensor Networks, Ubiquitous and Trustworthy Computing (SUTC'06), 2006, pp. 22-31.

[17] O. B. Akan, I. F. Akyildiz, "*Event-to-Sink Reliable Transport in Wireless Sensor Networks,*" IEEE/ACM Transaction on Networking, October, 2005, Vol.13, No. 5.

[18] Y. Iyer, S. Gandham, and S. Venkatesan, "*STCP: A Generic Transport Layer Protocol for Wireless Sensor Networks,* " proceedings of IEEE ICCCN 2005, San Diego, CA, USA, October, 2005.

[19] N. Tezcan and W. Wang, "*ART: an asymmetric and reliable transport mechanism for wireless sensor network,*" International journal of Sensor Networks, 2007.

[20] F. Yunus, N-S. N. Ismail, H. S. Ariffin, A. A. Shahidan, N. Fisal, K. Syed- Yusof, "*Proposed Transport Protocol for Reliable Data Transfer in Wireless Sensor Network (WSN)*" in IEEE Modelling, Simulation and Applied Optimization (ICMSAO), 2011, pp. 1-7.

[21] M. H. Yaghmaee and D. Adjeroh, "*A New Priority Based Congestion Control Protocol for Wireless Multimedia Sensor Networks*," International Symposium on World of Wireless, Mobile and Multimedia Networks, Newport Beach, 23-26 June 2008, pp. 1-8.

[22] X. Yin, X. Zhou, R. Huang, Y. Fang, and S. Li, "*A Fairness-Aware Congestion Control Scheme in Wireless Sensor Networks,*" IEEE

Trans. Veh. Technol., November, 2009, vol. 58, no. 9, pp. 5225–5234.

[23] M. M. Monowar, M. O. Rahman, A.-S. K. Pathan, and C. S. Hong, "*Congestion control protocol for wireless sensor networks handling prioritized heterogeneous traffic*," in Proceedings 5th Annu. Int. Conf. on Mobile and Ubiquitous Systems: Computing, Networking, and Services, Mobiquitous, 2008, pp. 1-8.

[24] F. K. Shaikh, *et al*., "*TRCCIT: Tunable Reliability with Congestion Control for Information Transport in Wireless Sensor Networks*," The 5th Annual ICST Wireless Inter- net Conference (WICON), Singapore, 1-3 March 2010, pp. 1-9.

[25] U.S. Visweswaraiya, K. S. Gurumurthy, "*A Novel, Dynamic Data Dissemination [D3] Technique for Congestion Avoidance/Control in High Speed Wireless Multimedia Sensor Networks*" in Proceeding of IEEE International Conference on computational Intelligence, Modelling and Simulation, 2013, pp. 351-356.

[26] M. A. Kafi, D. Djenouri, J. Ben-Othman, and N. Badache, "*Congestion Control Protocols in Wireless Sensor Networks: A Survey*" in IEEE Communications Survey and Tutorials, 2014, vol. 16, no.3, pp. 1369-1390.