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Comparative Study of Ad-hoc Routing Protocol for Oil and Gas Pipelines Surveillance Systems

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Abstract: Development and growth in all spheres of life has led to increased demand for modern technology such as video surveillance system. In this paper an oil pipeline surveillance system based on Mobile Ad-Hoc Network (MANET) as one of the means used to limit these risks is designed, implemented and evaluated. The MANET is infrastructure less (self-organized) wireless network, where each node can work as host (camera) and router at the same time. The topology design of oil pipeline imposes several constraints on the amount of video can be transmitted through the network depending on the size and the rate of the packets generated by each camera. Two types of routing protocols are examined for the proposed surveillance MANET, reactive (AODV) and proactive (OLSR). The results of comparison under different network loads and packets rate show that the AODV gives better performance over OLSR in terms of throughput, Packet lost, PTR and overhead. Therefore AODV protocol can be considered as strong candidate to be used in MANET wireless networks for oil and gas surveillance system.

Keywords: Video surveillance system, Pipeline monitoring, MANET, AODV, OLSR.

1. Introduction

In the recent years, there has been a growing interest in video surveillance applications and monitoring systems. The reasons for this interest is the entry of these systems in different applications field, including industrial, agricultural, military as well as scientific These applications researches. require monitoring to reduce the effort and costs; However, one of the most important goals of surveillance systems is to get information about the behavior and location of the foreign objects within certain sensing environment, as well as monitoring the performance of a particular system [2]. Video surveillance can be used in general surveillance systems, oil and gas industry, fire emergency, motorway monitoring and smart home [3][4]. These networks are found everywhere in multiple applications of the real world such as remote monitoring, environmental monitoring and surveillance systems [1].

Surveillance systems for oil and gas pipelines represent a combination of cameras, sensors, or both to closely monitor specific locations and can be constructed using wired or wireless networks. Each type has specific

features and limitations [5]. Wireless networks gain many advantages against wired networks such as mobility, cost-effective and adaptability [6]. Wireless network technology can be divided into infrastructure-based and infrastructure-less (Ad hoc Network) [4].

Traditional design of the surveillance systems on the basis of infrastructure wireless networks are depend on the collect and send information to a predefined site such as, base station or server for the purposes of processing and observation. The cost of traditional system will be very high when the monitored area becomes very long. Thus, more base stations are required. Increasing the number of base stations leads to increase system cost, interference problems, handover problems, high power consumption, and complicate the system management [7]. Therefore, designing a surveillance system based on infrastructure-less network (Ad-Hoc) overcomes these problems and provides efficient network operation.

Wireless camera networks can be used for long distance monitoring application. Most of these networks (wireless camera networks) were built on the basis of wireless infrastructure network. This type of network requires base stations (access points or routers) to connect



camera nodes with each other and to connect these cameras to control room. Therefore, the number of base stations will increase whenever the distance is increased. Consequently this will negatively affect the total cost and system complexity.

In this paper we design Visual Surveillance System (VSS) for monitoring an oil and gas pipelines based on mobile Ad hoc network (MANET) without any additional infrastructure. The proposed system is able to monitor the crashes (undesired events) which may happened over oil and gas pipelines. Since the MANET do not need a centralized node for communications, all nodes in MANET network can communicate directly to any other nodes within its radio range. However, this modification creates a routing problem that need to be treated well. Thus, the paper evaluates compares and analyzes the performance of different routing protocols techniques used in Ad-Hoc networks, like: On-Demand Distance Vector (AODV) and Optimized Link State Routing Protocol (OLSR). The reason of choosing these two types of protocols is to test the proposed system in reactive and proactive protocols, in order to choose the best routing protocol.

The rest of the paper is organized as follows. Section 2 illustrates the oil pipeline model design and parameters setup based on Ad-Hoc network. Section 3 presents the evaluation scenarios. Section 4 shows the analysis metrics and section 5 demonstrates the results and discussions. Finally, the paper is concluded in section 6.

2. ROUTING IN MOBILE AD-HOC NETWORKS AND ANALYSIS METRICS

Mobile Ad-hoc Network (MANET) is a group of independent wireless mobile nodes which communicate with each other without any infrastructure [8]. MANET provides the ability to communicate between nodes in the case of the infrastructure of communication is limited or non-existent. MANET is suffer from multiple constraints such as: dynamic topology, bandwidth, energy and security [9]. For instance, if two nodes attempted to communicate, the sender node must be sure that the receiver node within its transmission range or not, if yes, then the two nodes can directly communicate. Otherwise, contact will take place through intermediate nodes. Actually, each node acts as a host as well as a router. Therefore, the nodes must cooperate with each other to successfully swap data packets on the network [10].

One of the main problems in MANET is data packets routing. The routing protocols are aimed to determine short and stable path at less route discovery overhead [9]. Therefore, several routing algorithms have been proposed by researchers in MANET networks [9][11][12]. The most

prominent ones are: reactive (on-demand) and proactive (table-driven) routing protocols [10].

- Reactive Routing protocols: This type of protocol consume less routing discovery and maintenance overhead where the route is determined when needed by using flooding concept. Therefore, there are no needs to continuously update the routing table with latest route. It maintains active routes only. Reactive protocols seek to reduce the control traffic messages overhead at the expense of increased latency when discovering new routes [13][8].
- **Proactive routing protocols:** In these protocols, every node in the network has one or more routing tables which contain the latest routing information to other nodes. Hence, if any topology change occurs in the network, the protocol updates the routing table. Therefore, no route discovery delay related with finding a new route, as appeared in previous protocol. Proactive protocols usually distribute short path via periodic updates which result in increased routing overhead [13]. The proactive routing protocols are inappropriate for large networks as they require preserving the table content periodically in network. This causes more overhead which leads to consume more bandwidth [8].

It is essential for any form of MANET to analyze metrics used to assess the network performance. Channel capacity refers to the maximum rate at which data can be traded in the network across a certain communication channel expressed in bit/s. If the load exceeds the supported network bandwidth consequently, packet loss may occur due to congestion. This is because buffer in MAC layer may reach to overflow. Therefore, video quality and system performance may be reduced. Therefore, the analysis metrics which chosen to compare the performance of the two routing protocols (AODV and OLSR) are:

Throughput which is defined as the ratio of data packets received successfully to the destination per unit time over a communication channel. Throughput is usually measured in bit/s [10].

$$Thr = P_{rec} / T_{st} \tag{1}$$

where P_{rec} is total packets received and T_{st} is the total simulation time.

Packet Loss metric is one of the fundamental metrics in MANET that has affected by multiple factors such as mobility, congestion and performance of the routing protocol used. It is defined as the number of dropped packets through the transmission [16].



$$P_{loss} = P_{snd} - P_{rec} \tag{2}$$

where, P_{snd} is total packets send,.

Packet transmission ratio (PTR) is one of the important factors which affect the performance of routing protocol in the network. It depends on various parameters such as packet size, number of nodes, transmission range and network structure [17]. It represents the ratio of total number of successfully received packets at the destination to all number of packets sent from the sources [17].

$$PTR = (P_{rec} / P_{snd}) \tag{3}$$

On the other hand Average packet transmission time (delay): it is the average amount of time taken by all packets to go from source (camera) to destination (base station or gateway).it includes packet queuing time, processing and propagation delay [10].

$$T_{delay} = T_{rec} - T_{snd} \tag{4}$$

where T_{rec} is received packet time.

Finally, protocol overhead represents the control signals used for discovery and maintenance the route in the network. It represents the total number of routing packets generated for route discovery and route maintenance during the simulation process [10]. Increasing routing protocol overhead has negative effect on the performance of the network as bandwidth consumption.

Packet rate is important parameter in the system performance that represents the number of packets generated by the camera node per second. If the source node (camera) injects more data than can be supported in the network, it results in high contention rates at the next nodes and will degrade the network performance. Therefore, the value of this parameter must be selected carefully to obtain good network performance [15].

3. OIL AND GAS PIPELINES MONITORING SYSTEM MODEL DESIGN BASED ON AD-HOC NETWORK

The proposed system infrastructure divides the oil pipeline into small segments (sectors) of 5 Kilometers each in length, and each sector contain 20 camera nodes separated in 250 meters length along the pipeline. These camera nodes are used to monitor any unwanted events occurred in the intended sector, as illustrated in Figure 1. In the suggested VSS system the packet rate varies from 2-40 (packet/second) using 1024 bytes as a packet size. The performance and reliability of AODV and OLSR routing protocols was evaluated when a triple crash occur (triple cameras start capturing and transmitting) as result of undesired events detected along the monitored sector.

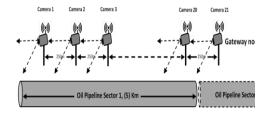


Figure 1. Proposed surveillance system architecture design

Camera nodes in surveillance system topology are distributed along an oil and gas pipes in a linear topology. This is accordingly to the shape of the pipeline itself. The location of nodes (cameras) under certain network topology represents important criteria in wireless surveillance system design. It may cause packet loss and thus affect negatively on the overall system performance. The network topology, number of nodes and their locations in the suggested surveillance system, impose many restrictions on the quantity of transmitted data over the network. These can be investigated together with the effect of routing algorithm is used when the proposed network is simulated.

The performance evaluation of different routing protocols have been investigated using OMNET++ ver. 4.6 simulator with network parameters as shown in Table I, whereas Tables II and III, show the parameter setup for each routing protocol AODV and OLSR, respectively.

TABLE I. PROPOSED NETWORK SIMULATION PARAMETERS

PARAMETERS	VALUE		
Network area	5000 m straight section.		
Number of camera nodes in one sector	20 camera nodes distributed in a single line topology.		
The separation distance between each two camera nodes	250 meter.		
The separation distance between the last node in the current sector and the gateway node in the next sector	250 meter.		
Data packet size	1024 Bytes		
packet rate	From 2, 4, 8, 20 and 40 packets / second.		
All the cameras use traffic sources	UDP.		
All the cameras use traffic pattern	CBR.		
MAC protocol used	IEEE 802.11g, DCF		
Simulation time	500 second		
Routing protocols used	AODV and OLSR		



TABLE II.	PARAMETER SETUP FOR	AODV PROTOCOL (7)	
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PARAMETER	VALUE
Hello interval	1000 ms
Active Route Timeout	6000 ms
Allowed Hello Loss	2
Net Diameter	35 hops
Time between retransmitted request	3 s

TABLE III. PARAMETER SETUP FOR OLSR PROTOCOL (7)

PARAMETER	VALUE	
Hello interval	2 s	
Refresh Interval	2 s	
TC message interval	5 s	
TC redundancy	3	
Willingness	3	

It is also assumed in the simulation of the suggested VSS system that the packet rate varies from 2-40 packet/second using 1024 bytes as a packet size. This assumption is essential in the test to evaluate the performance (reliability) of AODV and OLSR when a triple crash occur (triple cameras) as result of undesired events detected along the monitored sector. Finally, the performance evaluations, comparisons, and analysis have been carried out to measure five essential metrics, Protocol Throughput, packet lost, Packet Transmission Ratio (PTR), Transmission Time Delay and Protocol Overhead.

A. Protocol Throughput

Figure 2 shows the network throughput (in kbps) versus the packet rate. It is clear that for each protocol in Figure 2, AODV and OLSR, that increasing the packet rate means increasing the amount of data pushed into the network. This data push leads to an increase in throughput. Moreover, the network throughput for both protocols will decreases as the packet rate value reaches to 20 packets per second. This is because network congestion occurred as a result of pushing more data to Consequently, network. network throughput decreases. It should be pointed out that the throughput of AODV is greater than that of the OLSR routing protocol. This is because the on demand routing protocol (i.e., AODV) use less overhead messages than table driven routing protocol (OLSR), which means that the performance of AODV is better than OLSR Figure 2 shows the network throughput (in kbit/s) versus packet rate (in packet/second). There are two curves; each one indicates specific routing protocol (AODV and OLSR). For each protocol in Figure 2, increasing the packet rate means increasing the quantity of data which injected to the network. Therefore, it cause increase in throughput.

Moreover, network throughput for both protocols start decreases as the packet rate value reaches to 20 packets per second. This is because network congestion occurs as result of pushing more data to the network. Consequently, network throughput decreases. It should be pointed out that the throughput of AODV is greater than OLSR routing protocol. This is because the on demand routing protocol (i.e., AODV) use less overhead messages than table-driven routing protocol (OLSR), which means that the performance of AODV is better than OLSR.

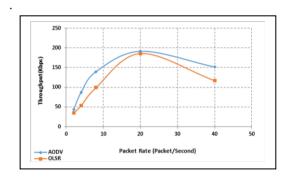


Figure 2. Throughput vs Packet Rate Using AODV and OLSR Routing Protocols

B. Packet Lost

Figure 3 compares packet loss versus packet rate, where the AODV outperforms OLSR with respect to the packet loss. Moreover, this figure also demonstrates that packets loss increased for both protocols when packet rate increased. Since, at high network load (triple crashes), the network ignore many packets if the buffer is full or if the packet has been buffered exceeds the time limit. Increase the number of transmission nodes (triple crashes) in the network combined with higher aggregate packet rate leads to increases the network congestion and the probability of collisions in some intermediate nodes which reduces the capability to drain queues.

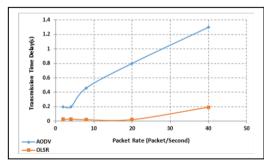


Figure 3. Number of Packet Lost vs Packet Rate Using AODV and OLSR Routing Protocols



C. Packet Transmission Ratio (PTR)

Figure 4 demonstrates the PTR versus packet rate. For both protocols, PTR start decreasing as the packet rate increases. Figure 4 clearly shows that the performance of AODV better than OLSR in light traffic load (lowest packet rate). However, the decrease of the average PTR in AODV is less than that in OLSR protocol. The reason for this difference in PTR is due to the nature of the each protocol. Where the AODV appears relatively faster response to any change in the network (link breakage); which reduces the probability of packets loss, consequently this make the decreasing level of PTR in AODV is less than OLSR

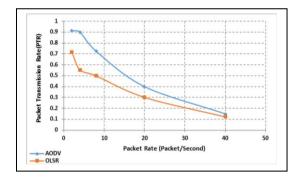


Figure 4. Packet Transmission Ratio vs Packet Rate Using AODV and OLSR Routing Protocols

D. Transmission Time Delay

Figure 5 shows the transmission time delay versus the packet rate, it shows that transmission time increased whenever packet rate increased in both protocols. Also this figure demonstrates that AODV has a higher time delay for all packets rate if compared with OLSR which is lower. This is because OLSR is table-driven protocol (proactive), since the routing table is establish at the initialization stage which enable this protocol to handle the data transfer more efficient. In other word, the arriving packets to the intermediate nodes can be forwarded or dropped immediately. In on demand protocols (reactive), packets are stored in buffer of the receiving node, until route discovery process take place. Moreover, OLSR protocol preserves all routes to destination nodes in the network by updating the routing information periodically. Therefore, when any breakage occurred between two nodes (source and destination) a new route can be found quickly.

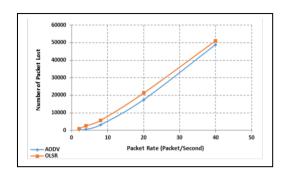


Figure 5. Transmission Time Delay vs Packet Rate Using AODV and OLSR Routing Protocols

E. Protocol Overhead

Figure 6 demonstrates protocol overhead (in Kbit) versus packet rate. This figure depicts that OLSR is higher than AODV in terms of routing overhead. Since the normal operation of OLSR protocol, is update routing information among network nodes periodically which result in high overhead. Furthermore, figure 6 also shows that AODV overhead is decreased while it increased in OLSR, especially when the packet rate is increased. This is because at high packet rate, routes are relatively long lived and the data can be transmitted during the route life time.

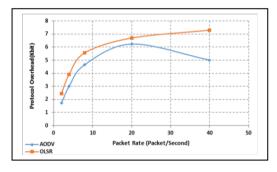


Figure 6. Protocol Overhead vs Packet Rate Using AODV and OLSR Routing Protocols

4. CONCLUSION

This paper studies the behavior of Ad-Hoc wireless network under different routing protocols (AODV and OLSR). The simulation scenario is based on the communication between camera nodes and base station in a MANET-based video surveillance system proposed for oil and gas pipelines. The outcomes of this study can be summarized as follow:

 AODV achieved higher throughput than than that of the OLSR since its routing overhead is less, and it has better capacity to drain data in the queues than OLSR, especially in moderate data rate (20 packet / sec). Therefore it records less packet lost. On the other hand AODV has better PTR than OLSR, since



it reacts quickly to the link breakage, and this fact reduces the number of lost packet in the AODV.

- OLSR has less transmission time delay (delay) than AODV since the routing table is established at the initialization stage. Thus when a packet is arrived at a node, it immediately forwarded or dropped whereas AODV make rout discovery process for each connection before sending the data.
- In spite of recording higher transmission time in AODV than that of the OLSR, the OLSR achieves highest throughput with less packet lost. The bandwidth and throughput are always the major metric to be considered in wireless networks. Therefore, considering the AODV protocol in wireless networks enhances the performance of these networks.
- Finally, the study contributes to the solutions of problems faced by wireless networks such as problems in video transfer and inefficient bandwidth utilization.

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