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Mobility based Cross Layer Optimization with QoS for HetNets

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Abstract: In this paper, different heuristics for cross-layer optimization for vehicular ad-hoc network are reviewed and analysed. Up to a large extent safety issues and traffic congestion in daily life can be resolved by integrating information and communication methodology into transportation infrastructure and vehicles. Link maintenance due to high mobility, congestion control, self-organization, dynamic behaviour and scalability makes it stiff to deployment in real time scenario. Performance of the different routing protocols in different scenarios are observed using different simulation tools by different authors in literature. It has been observed from the study that transmission range, obstacles, speed, scalability and road condition influence the performance of different protocols. Quality of Service metrics parameters like speed and mobility of vehicle influence the performance of network. For enhancement of the network performance in real time scenario latest communication technology and infrastructure plays an important role. Packet delivery ratio, goodput and throughput of vehicular ad hoc network can be improved by using optimized link prediction heuristic observed by simulation.

Keywords: QoS, Throughput, Jitter, PDR, delay, link stability, Cross layer design.

1. Introduction

Intelligent communication technology and self-organized characteristics of heterogenous network plays a vital role in smart & automated projects of future and existing wireless generations. In Smart city and home projects reliable communication technologies like WAVE, IEEE 802.11p, WiMAX, GPRS, LTE are used [1]. Optimization of space and complexity of a heuristic with their specific interfaces to flow parameters used to improve the performance of network was supported by modularization in traditional OSI reference model. Extra notification fields are used in protocol or database for information flow. Super-layer is designed by combining the services and functionalities of adjacent layers and joint optimization is performed at super-layer for uniform protocol without additional interfaces [2]. The main drawback of this approach is increased in time and space complexity, maintenance and system stability. A fixed layer and designed layer are used in Design Coupling without new interfaces. If PHY layer is modified to receive multiple packets, then MAC layer must be changed accordingly and when physical layer is fixed layer then MAC layer will work as designed layer [3]. In the stack, multiple parameters of protocol are adjusted to enhance the performance of different applications of Quality of service. Adjustment of parameters are done at run time for dynamic optimization and to achieve accuracy and complexity [4].

Application-oriented requirements depend on the end-user, for example, accurate, fast and reliable connection is required for safety app whereas QoS and reliable P2P connection is required for multimedia applications. Performance-oriented apps demands success rate higher using different heuristics with results minimum delay and maximum throughput [5]. Depending on the objectives, heuristics are decided to implement in different layers with cross-layer optimization. For safety apps, MAC-Network layer is used for fast and reliable communication to broadcast emergency messages.

Video streaming apps require direct communication between PHY layer and Transport layer due to heavy traffic. Design complexity, set of requirements, implementation costs and performance define the objective of cross-layer optimization. Interface-based algorithms with minimum alteration to OSI layer supports easy deployment with sharing of information between

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layers. Network performance attributes at different layers helpful in designing the network are characterized in Figure 1.

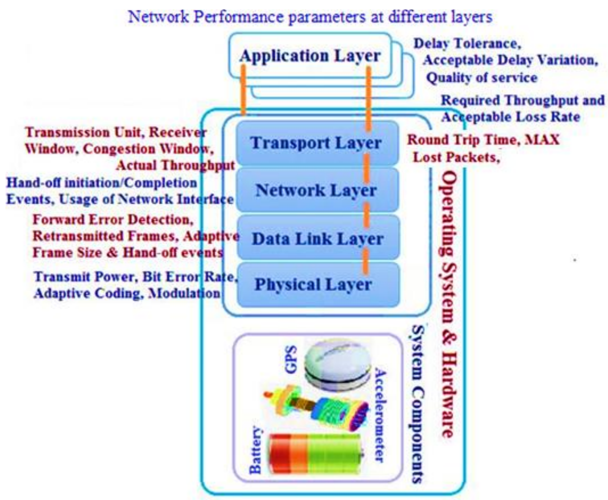

Figure 1. Network performance attributes at different layers

Another approach increases the computational time by using exchange of information using database in cross-layer design using appropriate interface [6]. Closer interaction between layers can optimize the cross-layer design by additional required functionalities into existing layers. In M4 strategy of cross-layer design which requires more memory and computational time at MAC, Network and PHY layers, network load, packet load and channel condition information are collected and shared between all layers. Engineers require to pay attention on routing protocol deployment with low cost factor, extendibility and advanced features [7]. With minimum communication overhead and deployment cost, Design coupling is stiffer to implement as related to interface-based technique which involves simple data structure. Cross-layer protocol designers must consist of complexity and cost factors while designing heuristics for heterogenous ad-hoc networks [8].

2. CROSS LAYER DESIGN IN HETEROGENEOUS AD-HOC NETWORK

PHY layer is responsible for communication between different IoT devices within transmission range considering environmental obstacles, time, mobility as important factors in wireless channel. For message transmission, signal strength, power, channel and transmission rate are important parameters at Physical layer [9]. Channel selection, transmission range and rate adaptation are critical parameters to enhance the performance of network at PHY layer. At PHY layer depending on Prx, link residual time (LRT) period is estimated. Based on LRT value scheduling, routing packet methodology and hand-off is decided to enhance the performance of the network. Cross-layer optimization is achieved in different phases like removal of noise from data, computation of values of LRT metrics, LRT renew and link quality prediction of communication [10]. Due to link existence between source and destination routers, minimum hop count and route election based on shortest route does not support better delay constraints. Higher E2E delay occurs due to large contention delay between nodes in highly dense area. At MAC layer individual link quality as well as route quality are important effective routing functions during routing of packets. Selection of network topology and communication constrains largely depends on these routing parameters which are transferred to network layer [11].

Mobility based routing and link prediction-based path selection heuristic enhances the performance of network using velocity, network topology and direction information gathered at the MAC layer [12]. MOPR estimates the active time of point to point links of intermediate nodes depending on vehicle information for next location evaluation. Dynamically election of most steady path with stable vehicles with constant speed in similar direction of source/destination vehicles, improves the performance of protocol. Using navigation systems and digital maps, longitude and latitude provides the position and observed speed of object is saved in the routing table. Overhead of rediscovery frequency of path selection is minimized in multipath routing protocol due to dynamically changed information causes performance degradation [13]. Chen et al. proposed R-AOMDV protocol which is an on-demand routing protocol for cross-layer, uses hop count in MAC layer to form routing metric and transmission range with improvement in delay and quality. Undelivered data packet announcement to adjacent vehicles with probabilistic relay improves the performance of protocol e.g. PDR with 6% and 5% in AODV-PR and AOMDV-PR [14].

Cluster based routing, neighbor information based on path quality, packet collision avoidance using segments and prioritization-based algorithms with quality of service supports are different methodologies used at transport layer in a heterogeneous ad-hoc network. In VANETs, DSRC protocol supports alerts, data monitoring using multi-hop broadcasting, driver's safety and sensitive data information with forged information. Security information like identities, certificates, warnings and security messages are broadcasted in a network by adversaries which is bogus information to increase the traffic congestion [15]. A pseudonymous message of a traffic jam of more than hundred vehicles is multicast to suggest them to select an alternative path for fake traffic jam scenario alert by an adversary. Consumption of computational resources of other node and communication channel jamming, the adversaries transmit inappropriate bulk messages in Denial of Service attack [16].

At transport layer, more stable algorithm is required due to communication between slow mobile network and fast wired network which uses UDP and TCP connections. Higher data packet loss occurs in VANET due to mobility, service disconnection and noisy channel. Transmission of data between vehicle and fixed internet access point and reduction in short communication and error prone scenarios is supported in Carbenet V2I protocol. Congestion information and lost packet information due to noisy channel is combined in Carbenet Transport protocol (CTP), which is used by all layers as a single process. 11 Mbps transmission rate using lightweight probing method in CTP provides optimal performance in network [17].

When a vehicle moves away from the transmission range of 500ms, QuickWiFi [18] senses dis-connectivity of the link with access point connection and selection and control message with beacon is transmitted to access point. AP selection is process is resumed and present status is notified by using optimized scanning heuristic [19]. Dynamic IP address and intermittent connectivity is maintained by CTP using proxy between server and vehicle. CTP connection remains active with dynamic IP address while link break using unique network-independent identifiers at end hosts to migrate across AP. At the application layer an API is used for feedback notification of connection appearance and reappearance using link determination heuristic. By using variable speed limit e.g. 40 km/h for peak hours and 100 km/h for non-peak hours by using data driven intelligent transport system is suggested in [20]. Multimedia communication services by using clustering heuristic is explored in [21] managed by VANET-LTE integrated architecture with improvement in throughput and end-to-end delay. Multi-hop communication in MCTP [22] for internet uses proxy-based architecture increases the base station service area. IP packet transmission between sender/receiver take place after the observation of feedback obtained from intermediate relay nodes. Congestion detection and network partition is indicated by ECN and ICMP messages which is useful information between V2V and vehicle to proxy with transparency [23].

3. NETWORK MODEL

Analytical model for identification of alternative routes, link availability and best route selection is presented in this section. GPS is used to determine the coordinates of an object at any instant of time and two adjacent nodes are aware of their positions and speed and prediction of moving away from each other transmission range is performed. The coordinate information of moving vehicle from location x to y in a direction using Cartesian coordinate system is maintained in routing table of node. Pythagorean theorem is used for calculation of Euclidean distance of vehicles which represents the closeness of two linked vehicles is more than the transmission range of radio is evaluated in advanced for maintenance of the link.

$$M = \binom{Xm}{Ym} \qquad N = \binom{Xn}{Yn}$$
$$V = \binom{VMx}{VMy} \qquad N = \binom{VNx}{VNy} \tag{1}$$

Node N initializes from coordinates (x_1, y_1) and node M from location x_2, y_2. With known velocity vector node moves with constant speed during simulation. After time duration T, location of nodes N and M after is kΔt, where step no and step length is k and Δt respectively:

$$N_k = N_0 + V_N.k\Delta t$$
$$M_k = M_0 + V_M.k\Delta t \tag{2}$$

The distance between two vehicles is N_k M_k = Ɗ, which is used for determining the node is out of transmission range for connection stability and connection initialization time t_0 and the time t_1 when node reaches the transmission range (R_1), lifetime T of connection between two vehicles is estimated as:

$$N_k = \binom{xN0 + Vnx.k\Delta t}{yN0 + Vny.k\Delta t}$$
$$M_k = \binom{xM0 + Vmx.k\Delta t}{yM0 + Vmy.k\Delta t} \tag{3}$$

$$|MkNk| = \sqrt{Mk^2 + Nk^2}$$
$$= \sqrt{}((xN0 + Vnax.k\Delta t) + (xM0 + Vmx.k\Delta t))2 + ((yN0 + Vn.k\Delta t) + (yM0 + Vm.k\Delta t))2 \tag{4}$$

A. *Availability of good connection*

Lifetime T of connection between two adjacent nodes is determined and then probability of each link availability termed as Good Connection Availability is predicted. Availability of a link to be good (GCA) is determined by equation:

$$P(G) = 1 - \frac{Dt}{Tx(range)} \tag{5}$$

At any instance of t, the distance between two nodes is $Ɗ_t$ and transmission range Tx(range) of two nodes is assumed to be the similar. Given equation is valid for Ɗt(T) and P(G)=0 for Ɗt=T. Good Path availability requirement of re-routing demands the alternative reliable path must be sustaining for long duration is called Good Path Availability. Highest availability of sustaining path over a certain period is estimated from available existing paths set. Epoch renewal length includes idle, success and collision states and used in expected length of the cycle E(t) is estimated as:

$$E(t) = \sum_{e\in(id,su,co)} pe\ Te \tag{6}$$

Where T_e is task duration and throughput is calculated as:

$$S = \frac{E[P]}{E[T]} = \frac{E[Packetsize]}{E[Cycletimelength]} \quad (7)$$

Where event probabilities are

$$p_{id} = (1-\tau)^n$$
$$p_{su} = n\,\tau\,(1-\tau)^{n-1}$$
$$pco = 1 - p_{id} - p_{su} \quad (8)$$

B. Closeness uniqueness

Average hop count nh using graph model in the interference model is reciprocal of the mean closeness uniqueness of the nodes. The average distance of a node to other nodes in ad-hoc network is closeness uniqueness.

$$CC_s = \frac{1}{\sum_{s \in V,\, s \equiv d \in V} h(s,d)} \quad (9)$$

Average Hop count is reciprocal of CC_s and Mean Hop count (HC) = 1/CC. High closeness uniqueness score represents that a node can reach destination with a short path or minimum numbers of hops and n_h is estimated as:

$$X_{mh} = \frac{2.1521}{\pi}\left(1-\frac{1}{HC}\right) = \frac{2.1521}{\pi}(1-CC) \quad (10)$$

C. Betweenness uniqueness

The betweenness uniqueness BC_k is represented as the time required by the source node s to reach the destination node d via node k using a shortest route. The number of different shortest routes between source and destination is $sp(s,d)$ and shortest routes containing the node k is represented with $spk(s,d)$. Then, the proportion of shortest paths, from s to d, which contain node k is:

$$BC_k = \frac{spk(s,d)}{sp(s,d)} \quad (11)$$

The mean betweenness centrality BC is the sum over all possible pairs of nodes:

$$BC = \Sigma_{s \in V} \sum_{s<>d \in V} BCk \quad (12)$$

4. NETWORK SIMULATION

In this section heuristics for heterogenous ad-hoc network with multi-hop technique for performance evaluation are simulated using Python and NS3. Analytical model as well as the performance model provides the better results validation as compared to custom discrete event simulation. NS3 simulation model includes channel model, transmission power and energy detection threshold at PHY and MAC layers for connection property which helps in routing.

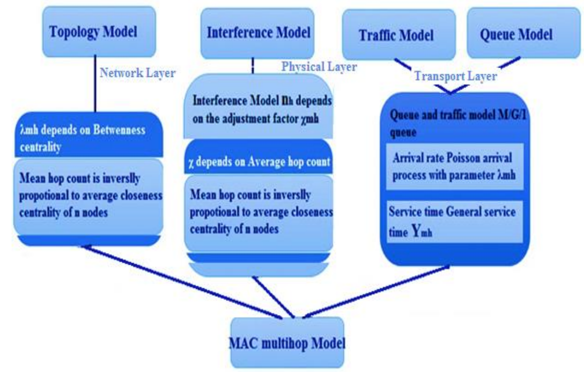

Figure 2. Performance Evaluation Model

MAC layer contains different route selection heuristics for different mesh configuration and 802.11 standard. Simulation work includes different arrival traffic assumptions and a set of traces are generated necessary to extract QoS by mesh packet dissector. Simulation results shows satisfactory QoS metrics. Unsaturated traffic, queue model, interference model between vehicles, network topology and general service time distribution model are important features for defining the performance model for Multi hop wireless network. Throughput, Delay and Jitter are the QoS metrics calculated for measuring performance. Average hop count and betweenness uniqueness for multi hop routing protocol is used measuring the performance. The proposed model for vehicles in a city with different scenarios is implemented in urban city and simulated in NS3 with a set of appropriate operational parameters to evaluate different network attributes. Different network topologies with different routing protocols using graph model is helpful in reducing computation time and costs of network implementation.

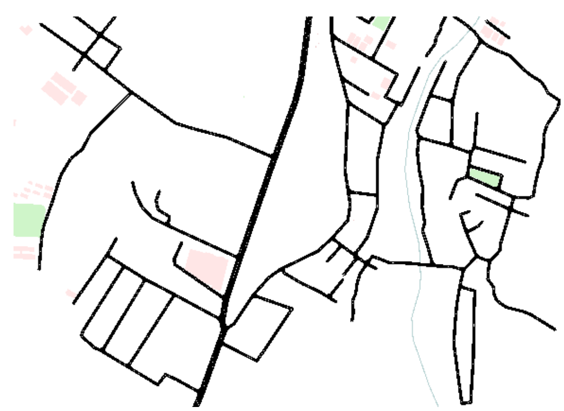

Figure 3. Route Map used for Scenario generated using SUMO

TABLE I. SIMULATION ATTRIBUTES

Simulation Attributes	Values
Nodes	100
Edges	222
Total edge length [km[	38.92
Total Lane length [km]	51.73
Average Updates per sec	4509.53
Loaded Vehicles	40
Departed Vehicles	35
Collision	-
Avg. speed	40
Begin time	0
End time	1000
Simulation Time	300 sec
Number of Vehicles	50, 100, 200
Number of routing sinks	10
Transmit Power	7.5 dB
Protocol	AODV, DSDV, Optimized link state
Wifi Phy mode	Ofdm rate 6 Mbps
802.11 mode	802.11p, WAVE
Mobility	RWP, trace file
Data Rate	2048 bps
Node speed	40, 60
Pause time	0
GPS Accuracy time	40 ns
Maximum Transmission Delay	10 ms
Area	300 * 1500m

5. RESULT DISCUSSION

Simulation with different set of parameters and traffic size from unsaturated to saturated condition with increased traffic rate and packet size is represented in table 1. Figures represents the average packet delivery ratio of different BSMs at different transmission ranges. Reactive protocols for dynamic behavior of ad-hoc network and mobility are adaptable, whereas proactive protocols are suitable for some scenarios of sparse networks where probability of searching multiple paths is minimum. As the density of vehicles increases, packet delivery ratio also increases with lower failure rate. Higher hop count increases the failure rate and collision of frames due to packet loss at MAC and PHY layer noisy channel.

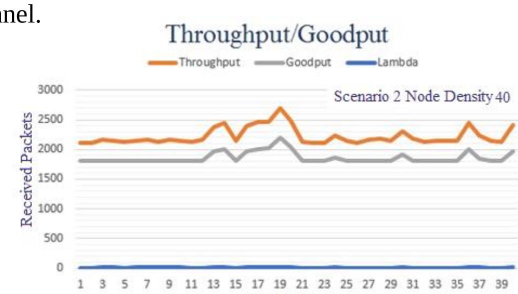

Figure 4. Throughput/Goodput and Lambda for scenario of 40 vehicles

As the transmission range increases, the performance of routing protocols enhanced while the performance degrades with higher speed. In dynamic behaviour of ad-hoc network caused by high speed, AODV is more adaptable as compared DSDV and DSR. Short transmission range causes, higher link failure and new path discovery in AODV routing table. Abundance of cached routes in DSR causes better PDR during short transmission range and mild object speed. Node density put great impact on the performance of different routing protocols. In higher dense area link break occurs frequently and randomly, so fast connection establishment between nodes are necessary. So in such scenario optimized link heuristic provides better performance as compared to other routing protocols.

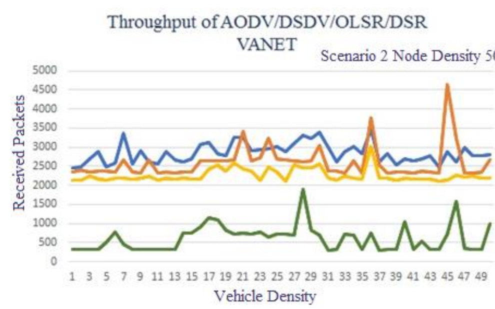

Figure 5. Throughput of different Routing protocol for node density of 50

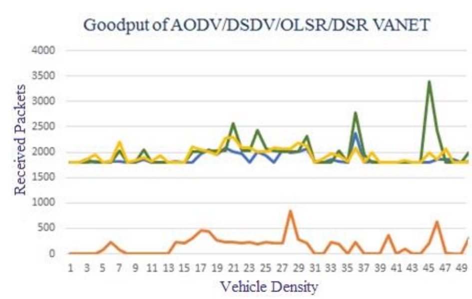

Figure 6. Goodput of different Routing protocol for node density of 50

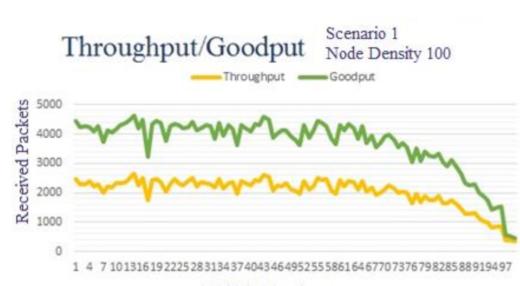

Figure 7. Throughput/Goodput for 100 vehicles

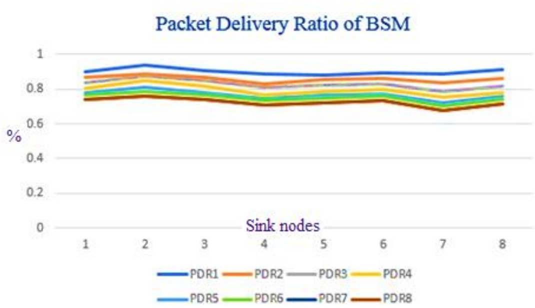

Figure 8. Packet Delivery Ratio of 8 Sink Nodes

6. CONCLUSION

Heterogeneous ad-hoc network with their specifications and background knowledge at numerous layers of OSI is presented in this paper. Different topics at various layers of ad-hoc network is deliberated in literature and classification is presented. Primary objective of VANETs is collision avoidance and congestion control for ITS applications. Significant intensive area of the VANET is high mobility which results in higher link failure rate. Important messages e.g. road congestion, accidental information and other vital messages need to broadcast to anticipated destinations. Study and performance of AODV, OLSR, DSR and DSDV routing protocols are detected in the different scenarios using SUMO and NS3. Object transmission rate, speed, mobility model and scalability change the performance of routing protocol rapidly. AODV shows better performance as compared to DSDV and DSR. Stability of OLSR is better as compared to other protocols in different cases of transmission range, density and speed. By using different set of input parameters computational time can be reduced less than 3 minutes. In future intelligent heuristics for controlling congestion using efficient resource management techniques for enhancing the network performance can be implemented, which is helpful in different real time scenarios.

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