A QoS Adaptive Routing Scheme (QARS) for Highly Dynamic Vehicular Networks with Support to Service and Priority

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Abstract: Implementation of real time critical, QoS on-demand, bandwidth 'hungry' applications over high speed dynamic vehicles, demand major research works to be carried out. Task of providing the optimal QoS over a specific period of time has been suggested as a challenging problem in current VANET research groups. This paper discusses on the importance of providing QoS using variable metrics such as speed, radio propagation range etc. Study analyzes the support of standard adhoc routing protocols such as GPSR, DYM0 over VANET, which shows best effort QoS utilization in response to demand on bandwidth in use over an established session for different type of services. This paper has discussed on vehicular parameters such as Vehicle Priority, Service Priority in order to improve QoS over a session consistently. Simulation test runs are generated using ns2[1] over a highway scenario map (support of VanetMobsim [2]), in order to ascertain the QoS efficiency over VANET.

Key words: QoS on-demand · Vehicular speed metric · Service priority · VanetMobsim

INTRODUCTION

A VANET can be assumed as an integration of multiple wireless / mobile networking technologies such as WiFi IEEE 802.11, WiMAX 802.16, Bluetooth, IRA, ZigBee for providing an effective communication between vehicles on dynamic mobility. Since the nodes are highly on mobility, data transmission is less reliable and sub optimal. Few features of VANET add complexity to network, which creates routing, security, QoS and faulty management features more challenging.

High speed vehicles with varying mobility constraints on a high way road and driver behavior are few factors due to which VANET’s possess different characteristics from the typical MANET models. Major characteristics are varying topology, consistent updates in network links, minimal effective network diameter with limited temporal, unlimited battery power and storage and functional redundancy [3]. VANET nodes can be considered as self organized and self manage the information in a distributed fashion without any centralized authority. VANET helps in defining safety measures in vehicles, streaming communication between vehicles, infotainment and telematics.

Road Sides Units (RSU - DSRC standard [4]) defines gateways as fixed or minimal in mobility on the road sides to provide intern connectivity to vehicles. Hence the vehicles and RSU form a mobile ad hoc network (MANET). Hybrid architecture consists of both infrastructure networks and ad hoc networks together.

In any generic network phenomena the concept of routing and its characteristics are highly linked with QoS. The major concern of VANET routing is that whether the performance can satisfy the throughput and delay requirements of such media streaming applications. An analysis of MANET routing protocols shows that its performance is not acceptable in VANETs [5] due to MANET’s feature of limited mobility. Its adverse effect leads to broken links, with high packet drop and overhead due to missing route repairs or failure. This phenomenon leads to low throughput ratio and high delay in transmission.

This research work proposes a QoS aware adaptive routing algorithm (QARS), which focuses on identifying optimal paths for effective routing in highly dynamic mobile ad hoc network such as VANET based on vehicle driver’s behavior. The process of selection and utilizing the optimal QoS route gets updated on transmission.
QARS works on route identification, route binding, update and deletion process based on the validation of adaptive QoS metrics, before the optimal route selection process between source and destination. This research work discusses on the survey and analysis the performance of GPSR [6], AQVA [7], DYMO [8] and proposed QARS based on simulation test beds and scenario mapping using ns2 simulator. The proposed routing scheme QARS has been designed and implemented as per the DSRC specifications [9] and IEEE 802.11p MAC.

The Aim of this Research Work Focuses On:

[1] Major challenge in protocol design in VANET is to improve reliability of routing data as well to reduce delivery delay time and minimize the number of packet retransmission.

[2] Abstract vehicular mobility is one of the major issue that leads to delay, hence designing of delay bounded routing protocols is also a challenge, since multicast carry and forward is an approach to deliver packets.

[3] Provide optimal QoS in cases when the node density is less, or when nodes are out of range of communication.

[4] Vehicles which require high quality service for service specific applications is a challenge in VANET, which had to be considered as ‘priority’ during routing.

[5] Vehicles with priority such as ambulances, patrol vehicles require safe transit even on a road congested, which is considered in this research.

To analyze the performance of QARS two different urban road scenarios were considered as discussed in Section-4. Real time road traces were created with VanetMobiSim [2] which can work on ns2 simulator [1]. The scenario maps consider varying speed of vehicles, vehicle priority, service priority, cross road intersections, lane information and traffic intensity on road at varying time intervals.

The simulated results show that QAR protocol’s performance is found to be better than protocols identified in literature survey for both the studied scenarios. Performance of metrics such as successful data delivery, average delay, been studied.

Literature Survey: Position based routing protocols such as LAR [10], DYMO [8], GPSR [6] requires prior knowledge of geographic location information of vehicles (from a GPS service) could be applied in VANETs for faster route information and performance. It had been noticed that position based routing protocols also suffer from severe geographic routing failures due to presence of “topology holes” [5]. The authors [11] propose spatially aware routing to overcome such drawback. But the effectiveness in optimality of spatially aware routing could not be judged due to spatial non-awareness. Hence it could be proved and it could be further enhanced in order to improve performance.

[9] follows an epidemic routing approach for VANET with tolerance support for delay. In sparse vehicular traffic [12], opportunistic forwarding mechanisms would be helpful for vehicle-to-vehicle ad hoc communications. AQVA [7] routing protocol is dynamic in identifying route based on driver behavioral parameters. This scheme had been simulated using VanetMobiSim over ns2, with support for real time road scenario. The major drawback of this AQVA is that it lags in maintaining route delay which is one of the major requirement of media streaming services in support of QoS.

The QAR protocols also support applications which are not necessarily delay tolerant. QAR routing protocols works on maintenance of an end to end path for streaming media data to reach its destination.

Receiver based hop selection is proposed at routing layer for most of the routing protocols [13, 14] or at MAC layer [4, 15]. The debate on which method is better is dependent on the performance of protocol in minimizing the effective end to end delay. Measures to minimize the hop distance between the source node and its neighbour were considered as one of the problem objective in [16, 17], where hop decision is taken at the MAC layer. Proposals in [11, 16] research on methods to improve route recovery strategies by proactively identifying potential dead end positions on a route or using channel overhearing capabilities of wireless networks to reduce the number of hops on the recovery paths.

[13] discusses on transmission methods where all neighbors can receive the entire packet, while any one neighbor can re-broadcast. This broadcast neighbor is selected based on time-based contention phase in which a node closest to the destination is considered. Geographical routing protocols, such as GPSR [6], GPR [14], require geographical node positions to route data between end-points. Once the local maxima is achieved, the algorithm stops since a new position is achieved and progress cannot be made based on node positions, which attributes to major failure.

The need for optimal, route aware adaptive routing protocol is required which can be designed and implemented based on vehicular mobility metrics, road map scenario. Hence QARS focuses on these issues as primary metrics as well provide QoS on demand for variable services on mobility.
QoS Issues in Vehicular Adhoc: Providing QoS for Multimedia applications in VANET is a challenging task because of its characteristic of highly dynamic mobility. Link breakage frequently happens because of the short lifetime of the connections and the unpredictable driver's behavior. In vehicular adhoc networks, the support for Quality of Service [18] is becoming an inherent necessity rather than an "additional feature" of the network. Following points insist on the need for designing QoS enabled ad hoc networks rather than adding such features as an afterthought.

- Rapid fluctuation of Wireless channel severely affects multi-hop flows.
- Packets contend for the shared media on adjacent links of a flow.
- Interference can affect transmissions at nodes beyond the neighbors.

To support QoS on multi-hop dynamic updatable paths, QARS should focus on end-to-end path for each hop between sources to destination as well other possible optimal paths for transmission. The physical and MAC layers are responsible for the QoS properties over a single-hop, while the routing layer is responsible for QoS metrics on an end-to-end route.

QARS (QoS Adaptive Routing Scheme): QARS design and simulation is primarily based on the vehicular behavior and communication model. The ns-2 simulations initially carried out over IEEE 802.11 for VANET shows the performance of wireless medium to be congested, due to overhead of periodic "hello" packets, which also degrades the performance of end-to-end data transfer.

QARS proposes a beaconless, distributed, receiver-based next-hop selection routing protocol to minimize this overhead, since VANET adopts non-uniform radio propagation. QARS introduces a simple modification of RTS/CTS mechanism in IEEE 802.11 standard. To identify the next best hop, an optimal multi-criterion prioritization function is adopted, using parameters as distance between each next hop and the destination, bandwidth required, received power level (which could be affected by noise and channel fading) and distance to transmitter.

QARS proposes two schemes of route connection between source and destination, based on radio propagation. (a) Connectivity between RSU and Vehicles (V2I), (b) Vehicle to vehicle (V2V). Since the intensity of nodes at cross-roads is higher, a RSU can help in maintaining the route between VANET nodes. The bandwidth of RSU can be shared between nodes at an instant; hence demand on QoS is controlled.

While VANET nodes on a high way road or lane may be high mobility the challenge lies in catering to demand on QoS.

Modeling QARS: QARS is modeled as a set of high speed vehicles on a straight highway in which any vehicle can establish connectivity with any other vehicle(s) traveling in same direction or opposite direction of its motion. Vehicles within the communication range can help in forwarding the data to be transmitted between the source and destination.

Here we assume the highway road R consisting of L lanes and connected to C number of cross-roads. Speed is not defined on the lanes as adopted in DVMO, hence any vehicle can cross another vehicle during its transit, hence it is assumed that each lane Li has variable speed limit Si. Each vehicle can communicate with another vehicle (in same direction or opposite direction), once the vehicle comes within communication range as per DSRC standards.

Highway Road - Ri
Lanes in road- Li
Cross Roads - Ci
Speed of Vehicle - [Vi, Si]
Service priority - [Vi, Se]
Vehicle priority - [Vi, Pi]

The traffic intensity of vehicles at any instant of time - t, where it can be gathered at any Ci or Ri or Li.

The intensity of vehicles on road or between lane(s) determines the fairness of providing the QoS on demand. As QARS adopt DSRC standard, IEEE 802.11 MAC is considered at link layer communicating at 5.9 GHz frequency. The RSU nodes at cross roads control the intensity of vehicular traffic over periodic intervals of time. Connection established between the source 'S' and destination or receiver 'D' can be provided as hop-by-hop connection using forwarding nodes 'Fi', or using nodes at cross road 'Ci'. Any 'Ci' can maintain the identity of vehicles within its radio communication range, as well
can communicate with its neighbour 'Cj' or 'Ch'. Vehicles can be classified as Source node 'Si' or destination node 'Di' and to forward data during transit as forwarding node 'Fi'.

**QARS Metrics**

- **[a]** $\beta$ - Radio propagation intensity of nodes.
- **[b]** $\eta$ - Delay between hop.
- **[c]** $\alpha$ - End to end delay.
- **[d]** $\delta$ - Packet loss (between source nodes and destination in bytes).
- **[e]** $c$ - Link capacity of transmitting nodes.
- **[f]** $\varepsilon$ - Average throughput at receiver.
- **[g]** $\tau$ - Route /hop identification wait time.
- **[h]** $\rho$ - Service priority.

QARS metrics are primary to identify the optimal QoS on demand for various type of services between differing nodes in communication. The following assumptions are adopted for any route to be optimal.

- **[a]** $\alpha$ is a major parameter to define an optimal QoS, only if a set of forwarding nodes between source and destination 'j' would be minimal ($<0.1$ ms) and number of hops (H) would be $=1$.

- **[b]** A VANET node 'I' is considered to be within the communication range of its neighboring node 'J' only when $\beta$ of I is acceptable within $\beta$ of J or an RSU. At any time 't', VANET nodes are assumed to be distance 'd' apart. If 'd' is large, then nodes may not be able to communicate with each other, instead intermediate forwarding nodes are required for connection establishment.

Hence always $1 < d_{ij}(t) < \alpha$, since $1$ is the minimal distance assumed between nodes i,j.

- **[c]** Two nodes 'i' and 'j' remain connected for a period of time 't', until the range lies between (1, $\alpha$), else disconnected. This also signifies the mobility speed of vehicles such that $d_{ij}(t)$ is dependent on $S[i,j]$.

- **[d]** A route is considered to be optimal when $\varepsilon$ is $>1$, being dependent on $\alpha < 1$ ms, $\delta$ lies between [0, 0.9] as well dependent on $\tau$ and $\rho$, which minimizes delay.

**QARS Procedure**

Three major functionalities are carried out by a generic adhoc routing protocol, such as discovery of new route, selecting an optimal route (from multiple valid routes available), perform route maintenance for transfer of data during transit and route update. QARS also adopts the following route management procedures for providing the required QoS.

**Route Creation and Route Maintenance:** Route Update and Optimal Route Selection (Route QARS OPR) using two procedures (as discussed in procedures Route Create, Route Optimal Discovery and Route Update).

**QARS works on route creation process**, where a route created is considered OPTIMAL, only if it can satisfy the required QARS QoS metrics (discussed in QARS Metrics). If an optimal route has been identified from a source to its destination and selected, then route maintenance procedure should be carried out to monitor the session in use. Density issues such as packet loss, session breakout, link failures (due to location change in forwarding nodes), delay (due to increase in number of hops) leads to implementation of route re-discovery procedure which selects the next optimal route available such that QoS is maintained for the session. Route maintenance process and re-discovery process involve extensive signaling and computation methods. Hence the desirable option is to select the optimal route with links of maximum possible lifetimes during the optimal route selection phase.

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**Fig. 2:** Vehicle to vehicle communication at different time intervals

(a) At time 't', Route [S,F1,D] and alternate route [S,F2,F3,D]

(b) At time 't+\Delta t', Route [S,F2,D], which is an Optimal route due to failure of Route [S,F1,D]
Route optimality poses a higher priority along with link delay, since it is more vital for the route quality in vehicular environments. The primary principle is that reliable routes that have longer expected lifetime and less hop numbers should be chosen instead of the shortest paths which may probably break soon and introduce high maintenance overhead. By taking this approach, the authors aim to significantly reduce the routing overhead and improve the traffic throughput of high speed vehicles in VANET.

**Procedure 1 Route_Create (Route_ID, Route_Next, QoS_Value)**:

Route Request (QARS_REQ) and Route Reply (QARS_RPL) at any node Fi
Variables:
S, D: Identity of source and destination VANET nodes
Route [ ]: Array route consisting of all temporary VANET node
Route_OPT, TempRoute: Optimal route and temporary routes from S to D
ζ: Vehicular priority
[Hopk]: ‘k’ number of hops between S to D, where ‘k’ being the radio propagation length
Ri (Li, Fi): Road segment with Lane segment where VANET node Fi is located
Ct: Cross-road route
τ: Route update Time Wait (TW) parameter
QARS_REQ: Route request packet
QARS_RPL: Route reply packet
QARS_OPT: Optimal Route

Upon receiving QARS_REQ (S, D, TempRoute) from any Fi
1: if (S == D) & (TempRoute ∩ Route) then
2: Route_OPT = TempRoute
3: Send QARS_RPL (S, D, Route_OPT)
4: return
5: else
6: send QARS_RER (0)
7: end if
8: if QARS_REQ = θ
9: if (Ri (Fi) + Ri (Fj)) ∩ (Ri (Fi) ∩ TempRoute) then
10: add Ri (Fi) to Route [ ]
11: end if
12: set Hop k = distance (Fi, Fj) τ
13: increment Hop k
14: end if
15: if Ri (S) == Rj (D) then
16: stop Hopk /* Fi is a better broadcast node */
17: end if
18: set τ = 0
19: QARS_BCS Route (S, D, TempRoute) /* broadcast route */
20: receive QARS_RPL (D, S, Route_RPL (Fj-1, Fj-1, -1)) from Fj
21: if τ * -1 then goto step 8
22: else
23: continue
24: if (Fi == S) then
25: store Route_RPL in Ci
26: forward QARS_REQ (S, Fi, ROUTE_RPL (Fi+1, Fj+1, D, ζ))
27: end if

**Route Optimal Discovery and Route Update**: Identifying an optimal route for a service between source and destination defines the process of satisfying the QoS on demand as per QARS metrics. Any service can be effectively accomplished if a best possible route or an optimal route among the available links is selected. The “capability” of defining an optimal route is based on the communication effectiveness for expected service in terms of fuzzy measure. Any node or link which is not “capable” to communicate as per optimality condition (as defined in Modelling QARS) is defined as Worst.

Optimization helps in providing an adaptive service for services which demand QoS consistently such as Streaming media delivery, content management feed, media conference. Optimization is provided (a) assigning route with required bandwidth, (b) maintaining and monitoring QARS metric on delay, packet loss, no of hops, radio propagation range.

**Procedure 2: Optimal Route**

QARS_OPR (NodeID_send(j), NodeID_recv(j), QARS_metric, Link_ID(j), ζ, μ), where j is set of route links identified between 1 to n

Variables:
S, D: Identity of source and destination VANET nodes
Route [ ]: Array route consisting of all temporary VANET node
Route_OPT, TempRoute: Optimal route and temporary routes from S to D
ζ: Vehicular priority
μ: Service priority
[Hopk]: ‘k’ number of hops between S to D, where ‘k’ being the radio propagation length
Ri (Li, Fi): Road segment with Lane segment where VANET node Fi is located
Ct: Cross-road route
τ: Route update Time Wait (TW) parameter
QARS_REQ: Route request packet  
QARS_RPL: Route reply packet  
QARS_OPT: Optimal Route  
Upon receiving QARS_REQ (S, D, TempRoute) from any Fi  
1: if ((S == Fi) || (D == Fj)) & ((TempRoute ∈ Route [ ]) then  
2: Route_OPT = TempRoute  
3: send QARS_RPL(S, D, Route_OPT)  
4: return  
5: else  
6: send QARS_REQ(S, D, TempRoute, μ, ζ)  
7: set Hopk = distance(Fi, Fj) τ /* hop count between nodes */  
8: set ζ = High || Low || Normal  
9: set μ = High || Low || Normal  
10: set τ = 0  
11: if QARS_OPT = θ  
12: if (Ri (Fi) * Ri (Fj)) & (Ri (Fi) ∈ TempRoute) & QARS_REQ (Fi+1,Fj+1, μ) then  
13: add Ri (Fi) to Route_OPT /* add the best route to Optimal Route */  
14: end if  
15: increment Hopk  
16: if Ri (S) == Ri (D) then  
17: stop Hopk /* Fi is a better broadcast node */  
18: end if  
19: send QARS_OPT (S, D, TempRoute, ζ) /* Optimal route */  
20: receive QARS_RPL (D, S, Route_RPL(Fj-1,Fi-1, -1)) from Fj  
21: increment QARS_OPT  
22: if τ > 1 then goto step 10  
23: else  
24: continue  
25: endif  
26: if (Fi == S) then  
27: store QARS_OPT in Ci and Ri  
28: forward QARS_REQ (S, Fi, ROUTE_RPL(Fi+1,Fj+1,D, ζ))  
29: end if  
30: endif

The step by step explanation of the algorithm is discussed in this section. Steps 1 to 6 explains the optimal route identified if the route is found to be shortest between the source and destination, with no other possible routes found in TempRoute list. Step 7 to 10, assigns default values for QARS_OPT metrics, Step 11 checks whether an optimal route is available in list QARS_OPT, else the process of adding the possible links based on the service request is added to QARS_OPT as explained in Step 12 to 14.

Fig. 3: QARS message flow

The phenomena of identifying the optimal route QARS_OPT is highly dependent on ‘Hop’ - the number of hops selected between source ‘S’ and destination ‘D’, μ and ζ, the vehicle, service priority respectively. The bandwidth on demand can be provided to nodes and services with high priority with help of VANET nodes which is discussed in Step 15 to 18. Step 19 requests the optimal route for session establishment, for which reply is received and session is established. If the wait time interval τ is maximum, then time out is declared and session is reset as shown in Steps 22 to 25. The best optimal route is stored in cross-road node Ci or Ri (Step27), while request is forwarded for a session route update in Step 28. The flow chart of QARS message handling routines is discussed as shown in Fig. 3.

This process simplifies the execution flow of QARS_OPT algorithm for QARS_REQ, QARS_RPL messages with error handling support in QARS_RER. QARS_RER is generated when a node or link had failed during transmission, the packets transmitted to the failed node has to be informed to neighbor forwarding node Ci. The forwarding node Ci at cross roads retransmits or broadcasts the data to avoid intermittent delay at receiver end.
Simulation Test Bed: The simulated behavior of vehicles can be conceived with specific QoS parameters such as “desired velocity”, “direction of vehicle”, “change of lane information”, which were used to model different types of road users. VANET nodes were classified into type Truck which can travel at maximum speed of 22.2m/s (approx. 60 to 80km/h) and vehicle of type Car which can travel at an average speed of 33.0m/s (approx. 80 to 120kms/hr). The simulations were performed at an average density of 4.2 vehicles per kilometer in a lane, representing less density or 20 vehicles per km in a lane, representing peak hour traffic [5, 16]. The simulation test bed is scripted in ns2 for three VANET protocol models namely GPSR, DYMO and QARS. The high way road of Bangalore city is chosen as test scenario map which is supported in VanetMobisim. (Fig. 5).

To model the test bed scenario, two different case studies were considered. The performance of QAR protocol is evaluated in high contention environments:

- A high way urban road environment with major obstacles which message using periodic “hello” and the standard 802.11 MAC protocol. VanetMobiSim supports the road map against real vehicular traces along the road [19].

- An urban environment without obstacles, using QAR’s proposed forwarding optimization routing scheme, across the roads.

A vehicular traffic generator “car-following model” proposed by Gipps [10], had been suggested. This model enables vehicles “on mobility” such that it can move at maximum safest speed to minimum speed as well avoids collisions. But the disadvantage of this model is that it does not support real time scenario road maps, hence as another alternate VanetMobisim is used for traffic generation. The test bed is executed using different scenario as shown in Table 1, the data rate is scheduled (Fig. 4b) with varying vehicular speed used on highway roads. The parameters defined are as per standard adopted in IEEE 802.11 MAC support for number of nodes and transmission / Receiver range.

Performance Analysis: Performance was measured at varying VANET node densities such as of 4, 7, 15 and 25 vehicles per kilometer and lane, corresponding to chosen traffic densities along a high way road map as shown in Fig. 5. Vehicles are categorized into ‘HighPriority’, ‘Ambulance’ and ‘NormalPriority’. The fig also shows Cross-road nodes which carry shareable bandwidth,
which all nodes can share for QoS on demand services. Ambulances and Highpriority nodes were given higher QARS QoS support compared to other nodes, which utilized the Cross-Road node more for utilizing its share of bandwidth. The NormalPriority nodes followed behind and used intermediate forward nodes for transmission.

QAR’s performance was better in controlling packet loss, an increase in throughput of around 15% compared to AQVA and 30% compared to GPSR using the IEEE 802.11 standard. In terms of average delay, QAR performed best, with delays as much as 85% lower than DYMO and GPSR. The proposed forwarding optimization provided noticeable improvements in the high contention scenario. The scenario with obstacles yielded better performance, even without using the optimization. This was the result of lower contention in the network as well as the fact that QAR protocols forward data along the roads and across the roads. Fig. 6 shows the performance of QARS in comparison with the surveyed protocol. It was noticed that delay for GPSR, DYMO was on average 12% high compared to QARS, as the number of nodes was slowly increased to 25, the performance of QARS differs to a greater extent with difference of around 90ms. On average QARS performs end-to-end delay of 125ms, while DYMO shows 192ms and GPSR 210ms.

Fig. 5: Digital Road map of Bangalore city - Test bed.

Fig. 6: End-to-end delay measured using HighPriority VANET node

Fig. 7: Packet Delivery Ratio at receiver nodes over VANET nodes
Fig. 7 shows the performance of QARS as PDR (packet delivery ratio), which explains the throughput or packet loss ratio (in %). From fig, it can be understood that performance of QARS and DYMO was high initially (average 100%), while GPSR delivered only 40% of transmitted data. As number of nodes was increased, it was found that QARS shows loss of 20% of its data but DYMO and GPSR loses around 90% of its data. The performance of QARS is comparatively better than DYMO and GPSR.

Conclusion and Future Work: This research work QARS focuses on providing QoS on demand for vehicles which works on bandwidth hungry applications. Major contribution from this research work focuses towards providing QoS for ‘on demand services’, for vehicle on dynamic mobility. Efforts on controlling vehicles with variable speed, lane change, vehicles at cross-roads are well established through simulated results. So far major works on priority for vehicles and services are not discussed, hence such works are not taken for survey as part of literature study.

Future Works That Can Be Focused Towards:

- Improving the reliability and creditability which is the major challenge in protocol design in VANET.
- A real time study on VANETs and experimental approach should be adopted to improve quality.
- Aspects on Driver behavior (drowsiness, drunken driving, rashness) should be considered for designing of delay bounded routing protocols since carry and forward is the mainly approach to deliver packets.

QARS can be improved in future with need to support on real time streaming services.

REFERENCES