ITS-Light: Adaptive Lightweight Scheme to Resource Optimize Intelligent Transportation Tracking System (ITS) – Customizing CoAP for Opportunistic Optimization

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Abstract. In this paper we aim to reduce overall resource usage and improve throughput of an intelligent transportation tracking application. Primary improvements in terms of bandwidth and latency are achieved using CoAP (Constrained Application Protocol). We propose a novel approach to adapt CoAP's reliability mode for data transfer by inferring vehicle's motion-state from tracking information. Further, we make salient modifications in protocol to achieve even better optimization and improved throughput and scalability while using non-reliable data transfer mode of CoAP. Proposed scheme is analyzed based on results obtained both in real and emulated environments.

Keywords: M2M · Resource optimization · CoAP · Sensor gateway

1 Introduction and Motivation

We propose ITS-light as a light-weight solution for tracking vehicle, focusing on application layer optimizations. The key focus here is to accomplish reduction in communication cost, and improve performance in terms of latency while making the solution more scalable. The use-case specific resource optimization is performed here through imbibing situation awareness of CoAP [1]. It is to be noted that overall communication cost directly impacts energy requirement of devices which is critical for any battery operated sensor gateway like mobile phone.

In ITS vehicles update a backend server with vehicle tracking information (VTI) mainly comprising the tuple: <location, time-stamp, accelerometer-samples>. Existing ITS application uses HTTP at application layer which we replaced by CoAP.

Our previous work in [4] presents an extensive study on two promising lightweight protocols, CoAP and MQTT [8] and establishes CoAP as a better choice. In this paper we primarily propose a novel approach to dynamically adapt reliability mode of CoAP to optimize resource usage. Precisely, while making an update, reliable or non-reliable data transfer mode is chosen depending on inferred situation, i.e. motional-state of vehicle. Further we propose a unique variant of non-reliable mode with a reduced

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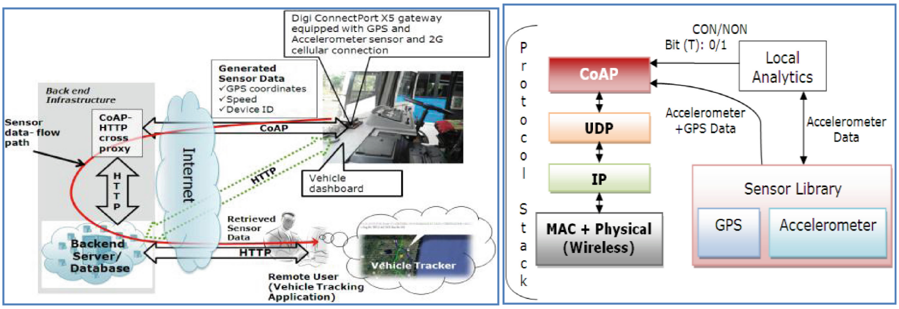
exchange to make overall ITS system even more lightweight when update-frequency of vehicle tracking information is high during fast movement of vehicle.

Our work draws inspiration from [5]. However, [5] deals with lower level of communication stack and proposes adaptation in terms of bit-rate, access point association, etc. using 'sensor hints'. It does not handle adaptation of application layer protocol characteristics for optimization of communication cost of sensors.

2 System Architecture

Figure 1(a, b) depict system architecture and functional components of proposed ITS respectively. Vehicles are equipped with Digi's ConnectPort-X5 M2 M gateway [2] having several sensors. Gateway accesses Internet using low bandwidth GPRS connection. Accelerometer data are collected over a configurable stipulated interval and VTI is periodically updated to back-end server by sensor-gateway.



(a) (b)

Fig. 1. (a) System Architecture. (b) Functional components of proposed adaptive ITS-light.

3 Adapting Data Transfer Mode Using Sensed Indication

CoAP supports two modes of reliability confirmable (CON), where the server replies back with an ACK to every request, and non-confirmable (NON) where the server does not reply with an ACK. Obviously, CON mode tries to ensure delivery through re-transmissions unlike the NON mode. A flag (T) [1] in protocol header determines CON or NON mode, where T = 0 signifies CON and T = 1 signifies NON.

We propose to make the behavior of CoAP intelligent depending on motional-state of the vehicle inferred by local analytics at in-vehicle sensor-gateway. Figure 2(a) illustrates the logical flow to achieve this. The vehicle should update in CON mode when it moves slowly or is at rest. Thus ensuring best-effort data delivery since next update is due after a long time. On the other hand, NON mode is used when it is inferred that vehicle is moving fast. In this case, since update rate is very high, a stray loss in flight of data is soon to be compensated with the flights coming in quick succession. Here reliability is traded-off against opportunistic saving in consumed

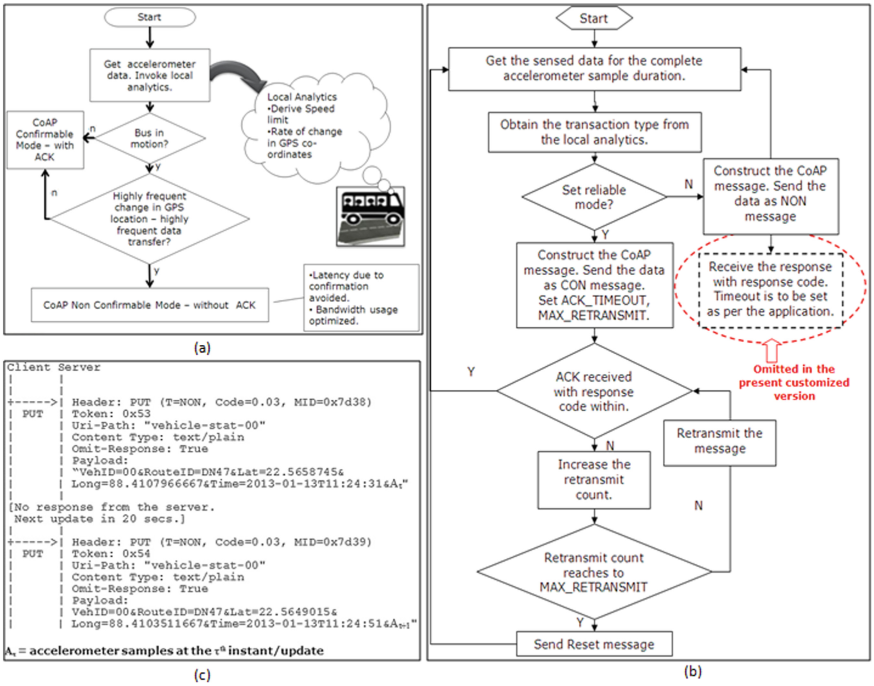


Fig. 2. Flow diagram: (a) reliability adaptation; (b) adaptation in the actual system. (c) An exemplary exchange with omit-response.

bandwidth and energy. To further reduce communication cost we have proposed salient modification in NON mode as explained in next section.

4 Application Specific Customization of CoAP

Although server does not respond back with an ACK in NON mode, still it responds back with a status code which is a zero payload message consisting of only 4 bytes of header, specifying "the result of the attempt to understand and satisfy the request" [1]. Therefore, even in NON mode, client has to wait for additional 4 bytes of response from server. So, for N numbers of NON updates there will be N*4 bytes of application layer responses where each response accumulates all headers from the underlying layers. N, over a period time, may be very large for large number of sensors with high rate of updates. These responses not only add to latency but add to overall load on network also. Even, from server side, catering huge number of update requests with status responses puts additional load. Thus addressing scalability issue.

When vehicle moves fast, status against every update with a fixed resource is deemed redundant. Optionally CoAP client may stop listening activity, thereby saving fair amount of energy. So, for further optimization, we have customized the protocol behavior by introducing an Omit-Response option which asks the server not to respond back and thus operates totally on a fire-and-forget basis (Fig. 2(b, c)).

5 Performance Measurement and Conclusion

Experimental Setup: Figure 3(a) depicts experimental setup inside a car. Laboratory arrangement [4] in (Fig. 3(b)) compares performance of modified NON mode against CON mode in terms of open-loop latency and bandwidth using a network emulator WANem [3], as real-field experiment does not allow control over communication channel. We have configured channel as 9.6 Kbps link with different packet losses (0 %, 10 %, 20 %).

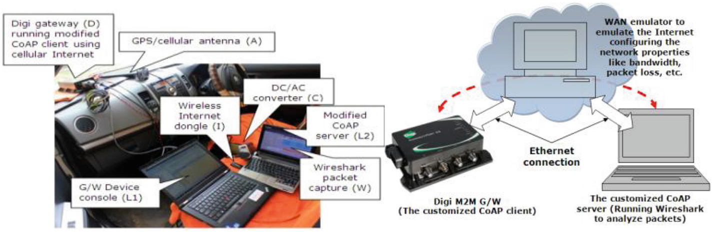


Fig. 3. Experiment set-up (a) on field (b) emulated environment.

Latency Measurement: Closed loop latency is measured by taking time difference between instants of sending information and reception of ACK at client end at in-vehicle gateway. The CON mode is essentially a closed-loop system while COAP-NON with Omit-Response is absolutely open-loop. For latter case open-loop latency is measured by taking time difference between transmit time from client and time at which message reached server (Fig. 4(a)). CON open-loop latency is still time difference between transmit time from client and time at which it 'finally' reaches server (Fig. 4(b)) with several retransmissions of same message in case message or ACK is lost or is delayed. Here time synchronization between backend server and CoAP-client is accomplished by using NTP [6].

Results, Analysis and Conclusion: Figure 5(a) shows average improvement in open-loop latency for proposed customized CoAP-NON over CoAP-CON in real field for varying vehicle speed. In case of former there is no duplicate transmission. Also it consumes less bandwidth (Fig. 5(b)) due to removal of return path and avoidance of duplicate and re-transmissions. Figure 5(c, d) establish advantage of trading-off

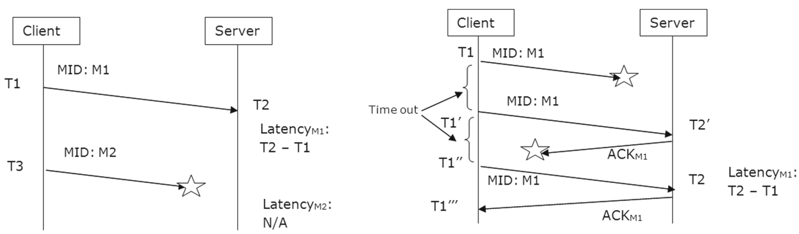


Fig. 4. Open-loop latency measurement (a) CoAP-NON with Omit-Response; (b) CoAP-CON

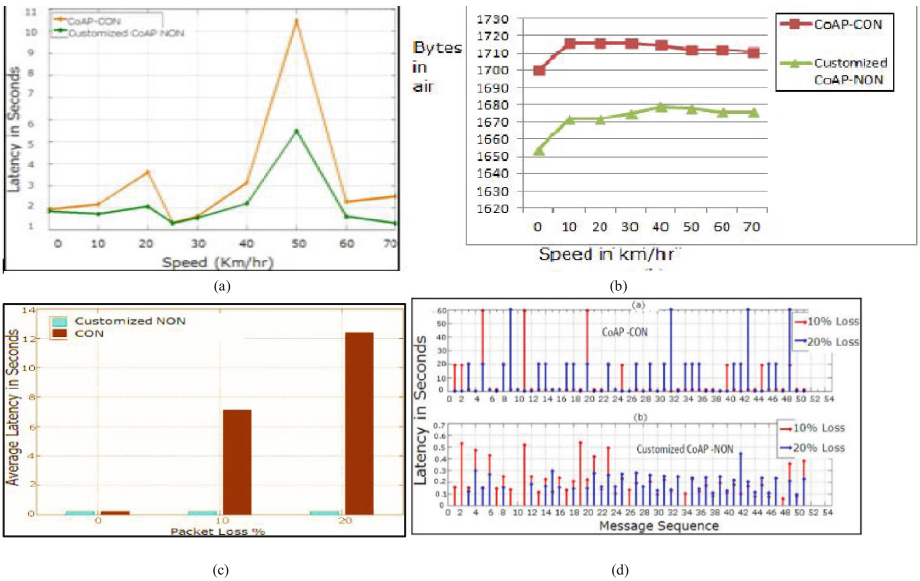


Fig. 5. For CoAP-CON and customized CoAP-NON. (a) open-loop-latency vs. vehicle speed, (b) total bytes transferred vs. vehicle speed (c) average latency vs. packet loss (d) a snapshot of latencies for continuous message instants for different packet losses

reliability against overall throughput. Here we have configured low bandwidth and lossy network using WANem. Figure 5(c), shows steady performance of customized NON mode despite lossy condition as transactions here are completely open-loop. Snapshot of consecutive instants of message exchange in Fig. 5(d) further strengthens this fact. Despite sporadic loss of data the overall rate of success and the achieved latency by the customized CoAP-NON shows noticeable improvement. Thus the proposed scheme promises to improve overall system performance, scalability, and should add value in terms of energy consumption as consumed numbers of bytes are directly proportional to energy requirement of the system.

Presently we are working on applying our proposed lightweight security scheme [7] to this solution for achieving an optimized secure solution.

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