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Quality of Service Extension to Dynamic MANET OnDemand Routing Protocol

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Abstract

This document describes extensions to the Dynamic MANET On-demand (DYMO) routing protocol in order to enable mobile nodes to discover and maintain QoS routes. DYMO is a reactive (on-demand) routing protocol designed for use by mobile nodes in multi-hop wireless ad hoc networks. Extensions of this document include the necessary addition to the routing table and the DYMO message element.

1. Introduction

The DYMO routing protocol specifies a reactive means to discover a route to the destination for MANET nodes. A source node disseminates RREQ message toward the destination node to discover a route to the node. Once the RREQ message arrives at the destination node, it responds RREP message back to the source node over the discovered path by unicasting. During such a route discovery process, intermediate nodes (i.e. nodes that relay the RREQ and RREP message) update its routing table based on the routing information that is present in those two messages for each direction. DYMO also offers adaptation to changing network topology, which can be occurred by the mobility of nodes as the main cause, by means of the route maintenance mechanisms [1].

In order to provide MANET nodes with QoS routes, extensions to DYMO message elements are required. These extensions specify the service requirements (say maximum tolerable delay, maximum tolerable jitter, and/or minimum bandwidth limitation) that must be guaranteed by nodes along a route from a source to the destination.

This document presents which extensions are required for support QoS in routing, how service guarantees are achieved by using the defined extensions without high impacts on the existing DYMO operations and how QoS routes are discovered and maintained are also briefly described.

The extensions of this document conform to the DYMO routing protocol (i.e. the the extentions to DYMO data structure specified in [1]).

In this document, the extension to routing table is first described and then two message element extensions, QoS Route Element (QRE) and QoS Route Error (QRERR), are presented for supporting QoS routing.

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [2].

2. Routing Table Entries for QoS Routing

In QoS routing, routing table entries can be defined differently according to the type of QoS model; per-flow based model such as IntServ model [3] or per-class based model such as DiffServ model [4].

In case of the per-flow based mechanism, the following entries may be added to the routing table of each DYMO router on the path. A routing table entry is defined for a flow to specify QoS requirements requested by the source (requestor) of the particular flow, where a flow can be identified by the pair of IP address and port number.

- Maximum Tolerable Delay
- Maximum Tolerable Jitter
- Minimum Available Bandwidth
- List of Sources Identifier Requesting Delay Guarantees
- List of Sources Identifier Requesting Jitter Guarantees
- List of Sources Identifier Requesting Bandwidth Guarantees,

where the Source Identifier consists of IPSourceAddress and Port number.

In case of the class-based model , on the other hand, the following fields may be added to the routing table of a DYMO router. Each routing table entry is defined for each pre-specified class, where a packet belonging to each class can be distinguished by DSCP (DiffServ Code Point) as specified in [5].

- Maximum Tolerable Delay
- Maximum Tolerable Jitter
- Minimum Available Bandwidth
- List of Classes
- List of Sources Identifier Belonging to Each Class

3. Extensions to DYMO Message Elements

In this section, we present two extensions to DYMO message element for support QoS route. The work especially considers the compact representation for use by mobile nodes in using of limited capacity, the future extensions for covering various QoS parameters and the support of the per-flow based mechanism and the per-class based mechanism as well.

3.1 QoS Routing Element (QRE)

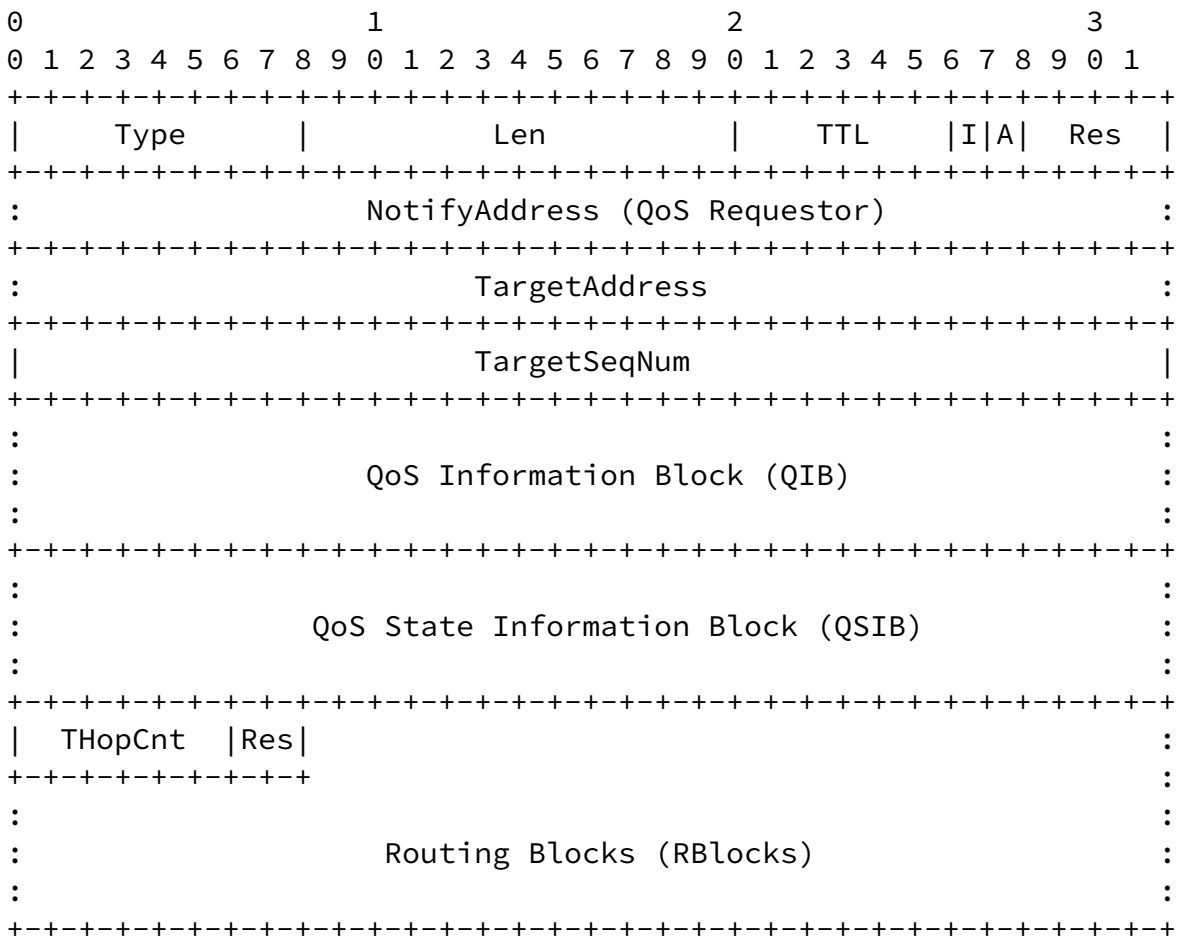


Figure 1. QoS Routing Element (QRE)

QoS Routing Element (QRE) is an extension to the DYMO Routing Element

(RE) in order to enable a source to discover a path that is able to guarantee the QoS requirements. The QoS requirements of the source are specified in the QIB (QoS Information Block) field.

Element Type (Type)
The Type field identifies that this element is QRE and the handling by nodes that do not implement or understand QoS extensions. The data structure of the Type is as follows.

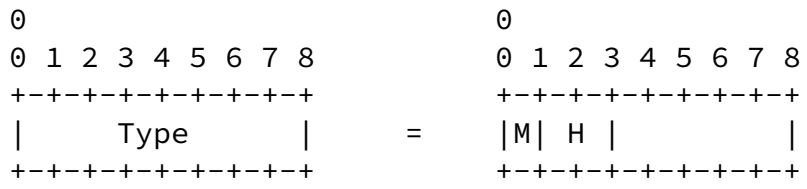


Figure 2. Type

In QRE, M bit MUST be set to one (1) in order to indicate that QRE requires notification via an UERR when QRE is not understood or handled by a node on the path. Therefore QRE MUST convey NotifyAddress field to which UERR is sent. As well as the H bits in the Type field MUST set to (11) in order to force a node which does not support QRE to drop the QRE packet without processing any other QoS DYMO elements.

NotifyAddress (QoS Requestor)
IP address of the source that have originally generated this QRE to request a particular service.

Most of fields conform to the DYMO message element specified in [2] except the newly defined two information block fields (i.e. QoS Information Block (QIB) and QoS State Information Block (QSIB)). Those two blocks are defined as follows.

QoS Information Block (QIB)
This field can be used differently according to the type of element message (i.e. in a route request and a route reply element with QoS extensions). In QRREQ message, on one hand, the QIB field indicates the service requirements that must be met

at nodes along a route to the destination. On the other hand, in QRREP message, the destination uses this field to inform the

route's resources available for the QoS requestor. The route's resources are gathered or updated by intermediate nodes and contained within the QSIB field during the route discovery process. The data structure of QIB field is described in Figure 3.

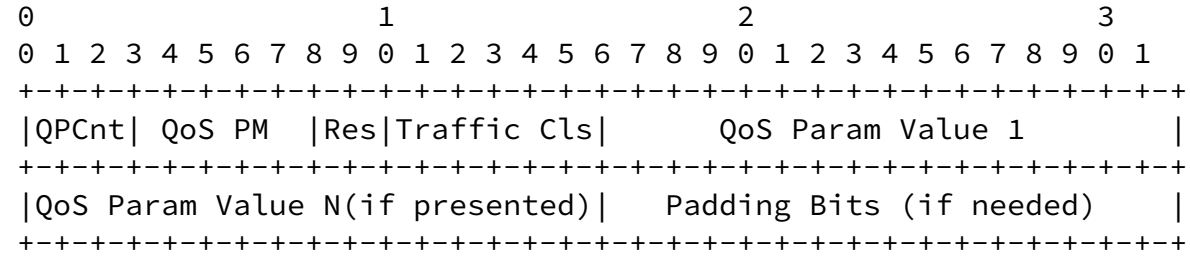


Figure 3. QoS Information Block (QIB)

QoS Parameter Count (QPCnt)
The most significant 3 bits, QPCnt bits, indicate the number of QoS parameters being presented within the QIB field.

QoS Parameter Mark (QoS PM)
The 5 bits marker of QoS PM field specifies which parameter is present in QIB to specify the service requirements. This field consists of the following bit marker.

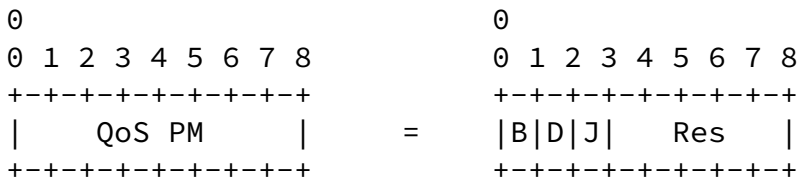


Figure 4. QoS Parameter Marker (QoS PM)

B-bit (B)
1-bit marker to indicate whether the minimum bandwidth is specified as one of the service requirements within QIB.

D-bit (D)
1-bit marker to indicate whether the maximum delay (end to end delay) is specified as one of the service requirements within

QIB.

J-bit (J)
1-bit marker to indicate whether the maximum jitter (end to end jitter) is specified as one of the service requirements within QIB.

Reserved (Res)
Reserved 2 bits for the future extensions (i.e. for other QoS parameters such as power of a node). Typically, these bits are set to zero (0) and ignored in any processing. In addition to these 2 bits, there exist two more bits at the next field (between QoS PM and Traffic Class fields). These Res bits also can be used for the future extensions. (At the time of writing this document, these two Res fields are conceptually distinguished in order to support easy to implement, i.e. byte based variable allocation in conventional programming language such as C.)

Traffic Class (Traffic Cls)
The Traffic Cls field allows mobile nodes to employ the per-class based mechanism (say DiffServ). This field is specified by using 6-bits code, called DSCP (Differentiated Services Code Points) that indicate a particular class.

QoS parameter value (QoS Param Value)
The number and the type of QoS parameters depend on the first 16 bytes of QIB as above addressed. If B and D bit are set to one (1), for example, there MUST exist two parameter value fields so that the padding field does not needed. QoS Param Value fields are defined as follows.

- Minimum Bandwidth Requirement
16-bit number, measured in kbits/second (kbps). The maximum value is about 131 Mbps (2^17 - 1 kbps). If the required bandwidth is less than 1kbps, the value is set to one (1) That is, the least bandwidth requirement the source requires is 1 Kbps.

- Maximum End to End Delay Requirement
16-bit number, measured in milliseconds (ms)

- Maximum End to End Jitter Requirement

16-bit number, measured in milliseconds (ms)

Padding Bits
The Padding field of QIB is used to confirm to DYMO message element. If QoS PCnt is even number then these bits are set to zero (0).

QoS State Information Block (QSIB)
In QoS routing, intermediate nodes along a path to the destination should inform the destination about its current state of resources in order that the destination is able to decide the optimal route among route candidates. The number and the kinds of QoS State Value depend on the QIB field. As an example, if a source specifies a delay parameter as a QoS requirement (i.e. D bit in QoS PM field is set), there MUST exist a QoS state value in SIB for presenting a delay value on candidate paths. In this case, all intermediate nodes MUST accumulate its measured delay. The data structure of the QSIB is illustrated in figure 5.

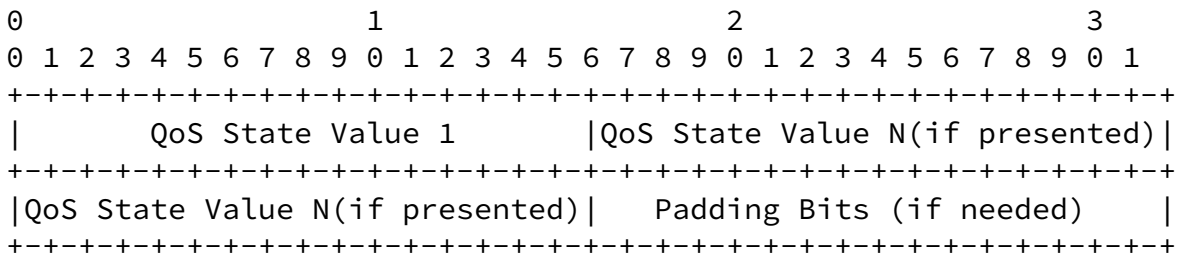


Figure 5. QoS State Information Block (QoS SIB)

3.2 QoS Route Error (QRERR)

QoS Route Error (QRERR) is an extension to the DYMO RERR message ele-

ment. QRERR message element is generated when an intermediate node realizes a lack of ability to maintain the QoS guarantees for a specific route. The data structure of this element is as follows.

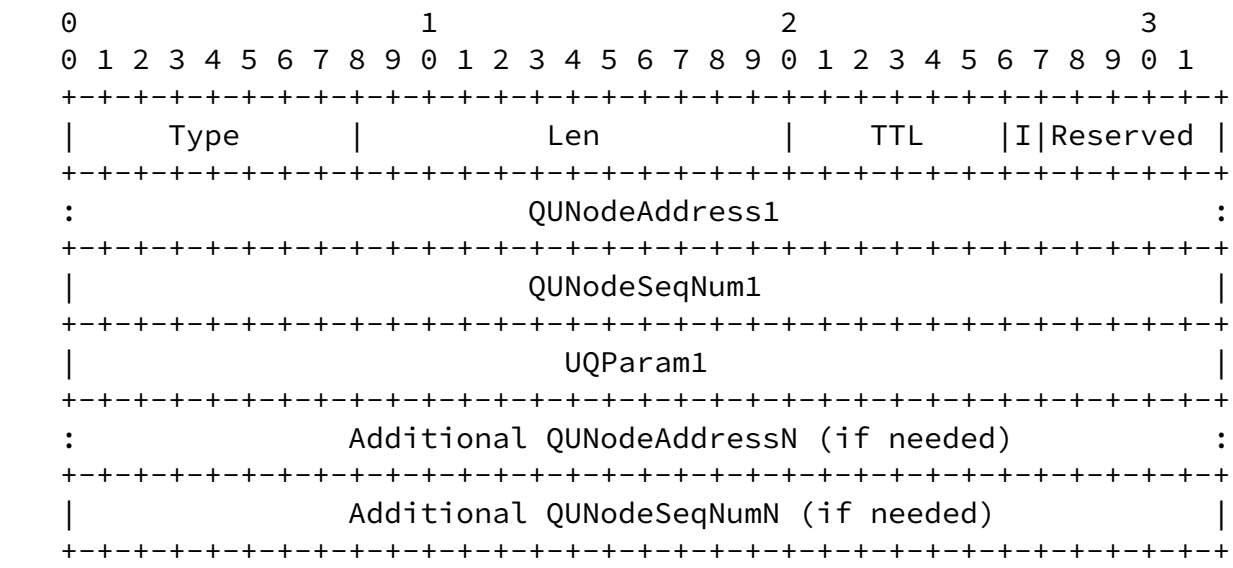
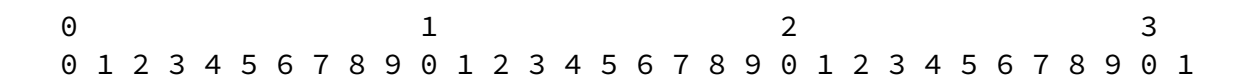


Figure 6. QoS Route Error (QRERR)

QoS Unsupported Node Address (QUNodeAddress)
The IP address of the node that cannot guarantee QoS any more.

QoS Unsupported Node Sequence Number (QUNodeSeqNum)
The sequence number of the node that cannot guarantee QoS, if known; otherwise this field set to zero (0).

Unsupported QoS Parameter (UQParam)
The main difference between RERR and QRERR is the UQParam (Unsupported QoS Parameter) field which is used to inform the QoS requestor about which QoS parameter is no longer available for the originally specified QoS requirements. Once the QoS requestor receives the QRERR, it re-builds a QoS route process based on the unavailable QoS parameters if it still has packets to deliver. This field is illustrated in figure 7.



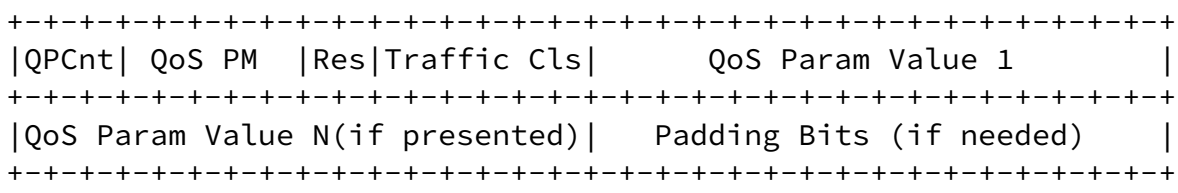


Figure 7. UQParam field

All fields are equivalent to the fields of QIB in the QRE message element but differently used. QoS PCnt indicates the number of scarce resource and each of their kinds are marked in QoS PM filed to identify the next fields (i.e. which parameter(s) is (are) present in UQParam field).

QoS Parameter Value
The QoS Parameter Value field reports the measured QoS parameter(s) that fails to meet the originally requested QoS. If a particular node is aware of higher delay than the maximum permissible delay, the measured delay is reported to the QoS requestor.

The QRERR message MUST be delivered to all QoS requestor potentially affected by the change in the QoS parameter.

4. QoS DYMO Operations

4.1 QoS Route Discovery

Like DYMO routing procedures, a QoS route is also discovered by means of two way handshaking consisting of a route request and route reply cycle. Instead of DYMO RREQ, the source (QoS requestor) disseminates QRREQ (RREQ with a QoS extension) to the destination. QRREQ message elements therefore should contain required QoS parameters as well as the QoS reporting information on the path that the message has been experienced. Thereafter, the destination node decides a correct route that can meet the QoS requirements and then sends QRREP (RREP with a QoS extension) to the source.

Ahead of re-broadcasting a QRREQ message by an intermediate node, the

node must check its resources whether it is available for the QoS requirements contained within the QRREQ message during the route discovery process. Thereafter, if resources are enough to meet service requirements, the intermediate node updates QoS information that is present in the QRREQ message to inform the destination about the current QoS states related to the path.

That is, QRREQ should contain two different fields. One is used to specify the QoS requirements of the source (i.e. QoS requestor) that must be met at nodes through the path. The other field is used to inform both the QoS requestor and the destination that selects a proper QoS route the current network conditions such as delay, jitter, and/or bandwidth.

In case of delay and jitter, intermediate nodes accumulate each of their measured delay and jitter value to the corresponding value of the received QRREQ message. For this reason, the destination can be aware of the end to end delay and jitter along the path.

In case of bandwidth (i.e. capacity to transmit), the node compares its measured value with the value of QSIB field in the received QRREQ message. If the measured value is smaller than the value of the message, the field is updated to the measured one. This field allows the destination to be aware of the actual minimum bandwidth over a route from the source to the destination since the value of QSIB is always bigger than the minimum value that the QoS requestor requires. If it is not the case, a node MUST drop the QRREQ message since there is not enough bandwidth to guarantee the required one. Such a way allows the QoS requestor to be able to increase the minimum bandwidth requirement according to the network condition dynamically.

In QoS enabled DYMO, M-bit MUST be set to one (1) and H-bits MUST be set to (11). Therefore, if the QoS extended element is not supported or handled by the processing node, the node MUST send a UERR to the NotifyAddress (QoS requestor) and drop the message to prevent that unsupported message is not propagated further.

In DYMO, I bit of RE message indicates whether the element has been ignored by some intermediate nodes. Therefore, in QoS DYMO, if the I

bit is (1), the QRE message MUST be dropped.

4.2 QoS Route Maintenance

In order to react to changes in the network resources, nodes monitor their links under the aspect of QoS. When a node is aware of the fact that resources of its link is no longer available for the QoS

requestor, a QoS-Route Error (QRERR) is sent to the QoS requestor to inform the current unavailable QoS parameters of the route. Once the requestor receives the QRERR, it re-builds a QoS route process based on the unavailable QoS parameters if it still has packets to deliver.

5. Security Considerations

This document does not discuss any special security concerns in detail. The protocol of this document is built on the assumption that all participating nodes are trusted each other as well as there is no adversary who modifies/injects false route elements to corrupt the QoS routes.

However, support of secure routing protocol is prerequisite for launching a secure communication in the presence of adversaries. In such an environment, most of all MANET routing protocols including DYMO are vulnerable to many kinds of attacks. It is fairly easy to inject fake routing messages or modify legitimate ones so that network operation would be heavily disturbed (e.g., by creating loops or disconnecting the network). Therefore, it is necessary to find a means to authenticate/verify control messages to discover and maintain a proper route. Especially, QRE message MUST be authenticated to enable nodes participating in QoS DYMO routing protocol to assure the origin of the QRE message.

References

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