Route Optimization Mechanisms for Internet Applications in Mobile Networks: A Survey

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Abstract

The use of mobile networks is rapidly increasing day by day. There are two aspects in mobile networks such as host mobility and network mobility. The protocols used for host mobility takes care of only single node to be connected with the internet. But, the protocols used for network mobility takes care of whole network to be connected with the internet using mobile router. The need for NEtwork MObility (NEMO) support is inevitable in mobile platforms such as car, bus, train, air-plane, etc. The Mobile Internet Protocol version 6 (MIPv6) and NEMO Basic Support Protocol (BSP) is used to support host mobility and network mobility, respectively. The NEMO BSP introduces several advantages, such as reduced signaling, increased manageability, reduced power consumption and conservation of bandwidth when compared to MIPv6 to be used in the mobile platforms. The NEMO BSP also suffers from a number of limitations, like inefficient route and increased handoff latency. The recent researches on NEMO have proposed several Route Optimization (RO) schemes that solves inefficient route. Though the proposed RO mechanisms solve inefficient route, it also has limitations such as signaling overflow, complexity and processing overload, delay during handoff, security breach, etc. The objectives of this survey are to identify, classify RO mechanisms and to select suitable RO mechanisms to enhance Quality of Service (QoS) in different kinds of internet applications.

Keywords: Network Mobility, Route Optimization, Internet Applications, Signaling Overhead, Delay, Quality of Service

1. Introduction

The uses of mobile networks in education, health, agriculture, disaster management, governance, etc. are inevitable. The fast growth of mobile communication can bring rapid developments in various fields. The mobile technology is popular because services can be availed anytime and anywhere. It becomes the important sense of a human being. The mobile communication is penetrating in all fields. The mobile networks can support host mobility [1] and network mobility [2]. One of the emerging technologies is a mobile network that supports network mobility. It is greatly needed in mobile platforms such as planes, trains, ships, cars, etc. It becomes a most essential thing of day-to-day life. So, the demands for mobility are not restricted to single terminal anymore. It also includes set of terminals / a network.

Comparatively, providing Quality of Service (QoS) in wired network has low complexity, wireless network has medium complexity, mobile network with host mobility has high complexity and mobile network with network mobility has very high complexity. There is a need to improve QoS in mobile network with network mobility which has very high complexity. The need for QoS is important for various internet applications. This survey aims to identify and classify the various Route Optimization (RO) schemes and to select more suitable RO schemes for internet applications in order to provide better QoS.

As QoS can be violated, there is a need for a technique to predict reason(s) for deterioration in the QoS and to identify the algorithm(s)/mechanism(s) responsible for the deterioration [3]. Providing QoS in mobile network is a great challenge. Hence, there is a need for QoS-enabled RO schemes. This paper is organized as follows. Section 2 describes NEtwork MObility (NEMO) architecture. Section 3 explains the promises and problems in route optimization schemes. Section 4 highlights the need for QoS-enabled RO schemes for internet applications. Section 5 classifies the various RO schemes and Section 6 identifies the suitable RO schemes for various internet applications. Section 7 contributes for concluding remarks. Finally, references are listed in Section 8.

2. NEMO architecture

The Internet Engineering Task Force (IETF) has developed protocols to support mobility, i.e. Mobile IPv4 [4], Mobile IPv6 [1] and Network Mobility (NEMO). NEMO Basic Support Protocol [2] is an extension of Mobile IPv6 for network mobility whilst the network moves and remains connected to the Internet. A special device called Mobile Router (MR) acts as a gateway for the mobile networks to provide a connection to the mobile nodes behind it. The mobile network nodes can be mobile or fixed. The types of mobile nodes that can be supported by the MR are local fixed nodes, local mobile nodes and visiting mobile nodes. The local fixed nodes (LFN) are the nodes that cannot be moved and are supported by the MR to achieve connectivity. These nodes have the same home agent as the MR. The nodes that can be moved and belong to the mobile network as its home network are called local mobile nodes (LMN). The visiting mobile nodes (VMN) are the nodes that attached to the mobile network on a temporary basis and do not belong to the mobile network.

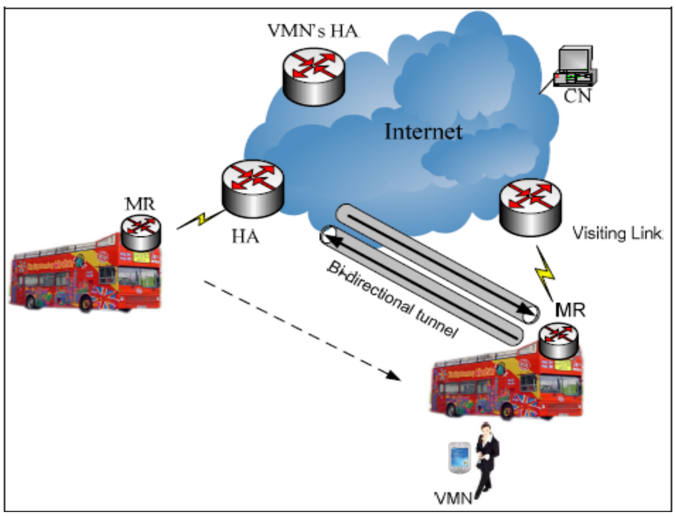

Figure 1. Establishment of bi-directional between HA and MR [5]

Consider Figure 1 as a mobile network in a real-world situation. A public transport bus forms a mobile network (MN) which consists of multiple mobile network nodes (MNNs) where the passengers carry mobile devices and MR acts as a gateway to keep the connectivity to the MNNs behind it. The MR performs a registration process when the bus at the bus station moves from its home network and attaches to a different network, i.e. a visiting link. The MR acquires a Care-of-Address (CoA) from the visiting link. The CoA is a temporary address provided by the visiting link to the MR. Once the MR receives the CoA, it sends a binding update (BU) message to its home agent (HA) in the home link. The HA receives the BU message and creates a cache entry binding. The HA replies the BU message with a positive binding acknowledgement (BA).

After the registration of the temporary address is complete, a bi-directional tunnel is established between the HA and MR where any packets from the correspondent node (CN) or MNNs are flows via the bidirectional tunnel. If a new passenger step into the bus bring along her PDA (i.e. a visiting mobile node) which configured with mobile IPv6, it can access the Internet through the mobile router in the bus. However, the VMN has a different home network from the mobile router therefore a bi-directional tunnel between the VMN and VMN's HA should be established. The processes involved are the same as explained above. The problems associated with NEMO BSP are discussed in the next section.

3. Route optimization: promises and problems

RO refers to improving the end-to-end path between a Mobile Network Node (MNN) and a Correspondent Node (CN). It also means that a mechanism that optimizes the transmission of packets or mechanism to enable packets to directly reach the mobile network by avoiding multiple tunnels through home agents.

3.1. Promises

The deployment of NEMO BSP incurs operational limitations and overheads, which can be alleviated by a set of NEMO Route Optimization (RO) schemes. The term "route optimization" takes a broader meaning in NEMO than in MIPv6. A RO scheme for NEMO BSP would refer to improving the end-to-end path between a Mobile Network Node (MNN) and Correspondent Node (CN). Some of the problems associated with NEMO BSP and the reasons for RO solutions are as follows [6].

- According to NEMO BSP, all packets traveling between the MR and the CN must pass through the bi-directional tunnel. It can lead to longer route, packet delay and affect QoS. Also a longer route would put extra processing load on the routing infrastructure and the probability of failure at a certain link would also be greater.
- Each time a packet goes through the bi-directional tunnel, an additional IPv6 header is added. This increases a packet size and reduces overall bandwidth efficiency. Also, if the packet size goes beyond the Maximum Transmission Unit (MTU) limit on a link it has to be fragmented, which can add to packet delay. Processing at the point of encapsulation also increases packet delay.
- All traffic emerging from the mobile network goes through a single line i.e. the home link. This can cause congestion. The failure of this link would influence all communication to and from the mobile network.
- In a nested network, if two MNNs wish to communicate, their packets have to pass through all upstream MRs and their corresponding HAs. This increases packet delay and packet size.

Addressing the above problems raises several issues that were reported in [7]. So, care must be taken to consider these issues when developing RO schemes to provide better QoS. The QoS-enabled RO schemes can offer better solution for various applications.

3.2. Problems

RO requires bypassing the HAs when packets are sent between CN and MNNs. Bypassing HAs gives rise to the following two major challenges which have to be addressed by RO schemes [8].

- How can a packet destined to an MNN reach the TLMR attached to the foreign network to which the MNN is attached (directly or indirectly)?
- How is a packet routed inside the mobile network after reaching TLMR?

The challenges are addressed by majority of the RO schemes that focus on optimizing route between a CN in wired network and an MNN. Addressing above mentioned challenges is not sufficient for optimizing route between two MNNs (intra mobile network communication [9]) that involves more encapsulation/ de-capsulation and longer route than those required in transmission of packets between a CN in the wired network and an MNN.

The challenge of RO in intra mobile network case (Intra RO) is how to route packets between two MNNs without letting the packet outside the mobile network; some RO schemes also address this challenge. Although our focus is on RO between CN and MNNs, the schemes that perform Intra RO are included because they also optimize route for communication between a CN and an MNN.

4. Need for QoS-enabled RO Schemes for Internet Applications

The internet applications used in mobile networks need to compromise in higher delay, higher error rate, and lower bandwidth compared to fixed networks. The customers not only need mobility but also quality [10]. The various internet applications such as file transfer, e-mail, internet telephony, video conferencing, etc., require Quality of Service (QoS) guarantees. QoS is a set of service requirements to be met by the network. It is also a competitive mechanism to provide more distinguished services by the service providers. The key to successfully addressing QoS issue is QoS routing. When addressing QoS in the wireless mobile segment, several unique and distinguishing issues emerge. Lower throughput, higher delay, jitter and higher bit error rates are inevitable in wireless mobile networks.

As different QoS-sensitive applications require different QoS guarantees, mobile users with active calls may have to adapt network dynamics as they move. In other words, some applications require stringent end-to-end delay, some require a minimal transmission rate, while others with no strict delay and / or bandwidth requirements may simply require high throughput.

The mobile network with network mobility has more impact on QoS parameters than a mobile network with host mobility when the whole network moves as a unit. As a result the packet delay may change and congestion level may vary. If the new location is overcrowded, the available bandwidth in the new location may not be sufficient to provide the throughput the mobile network was receiving at the previous location. Hence, Route Optimization (RO) mechanisms are necessary to guarantee QoS in mobile networks.

Generally, internet applications are divided into two types such as real-time and non-real-time applications. The non-real-time applications will wait for packets to arrive before the application actually processes the data. Some of the real-time applications are real-time interactive audio and video applications, one-to-many streaming of real-time audio and video applications and streaming of stored audio and video applications. The real-time interactive audio and video applications allow customers to use audio / video to communicate with each other in real-time. Real-time interactive audio and video are referred to as internet phone and video conferencing, respectively. In this class, delay between 150 ms to 400 ms can be acceptable.

The one-to-many streaming of real-time audio and video applications is similar to ordinary broadcast of radio and television, except that the transmission takes place over the internet. This class of applications is non-interactive and a client cannot control server's transmission. Delays up to tens of seconds can be tolerated. The streaming of stored audio and video applications are on-demand compressed audio or video files, which are stored on servers. For audio, these files can contain professor's lectures, rock songs, symphonies, etc. For video, these files can contain videos of professors' lecturers, full-length movies, video archives of historical events, etc. Delays on the order of 1 to 10 seconds are acceptable [11]. Some of the non-real-time applications are web access, file transfer, e-mail. These applications mostly have static content and they can tolerate long end-to-end delays and cannot tolerate packet loss.

Based on the above discussion, it is clear that each application requires different QoSs. So, different kinds of RO mechanisms are needed to provide better QoS for the internet applications. The selection of suitable RO mechanisms must be done to provide QoS. But, most of the mechanisms are not concentrating on all QoS parameters such as delay, bandwidth, jitter, packet loss, etc. This necessitates the need for a solution that takes into account QoS parameters.

5. Classification of RO Schemes

To address the problems mentioned in Sec. III, several RO schemes have been proposed in the literature and they can be selected based on the degree of RO. Abu Zafar et al., introduce a new class of schemes based on the the RO techniques proposed in [12], [13], [14]. The various RO schemes that have been proposed can be generally classified as follows [8].

- Delegation
- Hierarchical
- Source routing
- BGP-assisted

5.1. Delegation

In this class, prefix of the foreign network is delegated inside the mobile network. The concept of prefix delegation is simple, and provides optimal route with low header overhead at the cost of sacrificing location transparency. Moreover, sending BU to CN requires additional signaling along with requirement of protocol support (location management along with HA) from CN, making the schemes difficult to deploy. The schemes also do not focus on Intra RO.

5.2. Hierarchical

In the hierarchical class, a packet, rather than traveling through all HAs, reaches the foreign network either from MNN's HA (first HA) or traveling only through HA of MNN and TLMR. Unlike delegation-based approach, an MR does not send its CoA to CNs. The schemes in this class mainly differ in the use of TLMR's CoA or HoA for tunneling, techniques to convey TLMR's address to MRs, and routing of packets inside mobile network resulting in differences in signaling, memory requirement and degree of RO. Moreover, depending on the use of HoA or CoA of the TLMR, the number of tunnels used for communication differs among the schemes; number of tunnels affects degree of RO and header overhead. In addition, location management entities also vary among the schemes.

5.3. Source routing

In this class, RO is achieved by sending the CoAs of MRs to the CN which, like source routing, inserts the CoAs in the packet header to reflect the nesting structure of the MRs. This however, results in increased header overhead. Packets from the CN reach TLMR in an optimal route (without going through HAs); routing within the mobile network is done using the CoAs in the packet header. Memory requirement for routing entries is low because each MR needs to keep track of only the attached MRs as next hop. Schemes in this class notify CN about the CoAs of MRs in various ways that will be detailed in the descriptions of the schemes. Notification of CoAs to CNs sacrifices location transparency and deployability, and increases signaling. Methods of notifying the CN result in differences in signaling and overheads.

5.4. BGP-assisted

Unlike the schemes described so far, the schemes in this class rely on BGP [15] for mobility management. When the mobile network moves, BGP routers are updated to make necessary changes in the routing tables by making forwarding entries for the prefix of the mobile network. Information regarding the change of route of the mobile network is signaled to few routers that exchange the information with peers using existing routing protocols in the Internet. Therefore, routers contain routing entries to route packets to the mobile network irrespective of its location, and are responsible for location management. Schemes in this class mainly differ in the number of external BGP updates generated, and incurring other overheads for managing Intra RO.

In this survey, RO schemes under the classifications such as delegation and source routing are considered as they have the degree of RO as optimal. In other words, RO schemes under the classifications such as hierarchical and BGP-assisted are not considered as they have the degree of RO as near optimal or non-optimal. For more details on various schemes in the above four classes can be referred in [8].

6. Suitable RO schemes for internet applications

The selection of appropriate mechanisms at different layers is very important. The selection of coding schemes [16], network interfaces [17] [18], etc., are necessary in providing better QoS. This section concentrates on selection of suitable RO schemes to increase QoS in NEMO. The various RO schemes and its degree of RO and signaling overhead are given in table 1. It reveals that the degree of RO for all schemes is optimal. Hence, it is suitable for QoS-sensitive internet applications than RO schemes that offer degree of RO as non-optimal. It will ensure the QoS. In an effort to tradeoff issues, such as signaling, some schemes allow one or two levels of tunneling or some non-optimality in the route between a CN and an MNN. The level of tunneling or extent of non-optimality is referred as degree of RO. Signaling overhead refers the amount of control data needed to maintain RO for data transfer. RO schemes and its degree of RO and signaling overhead are given in table 1.

Table 1: RO schemes and its degree of RO and signaling overhead

RO Schemes	Degree of RO	Signaling Overhead
OPR	Optimal	Low
xMIPv6	Optimal	Low
PCH-based	Optimal	Low
Simple Prefix Delegation	Optimal	Medium
ND-Proxy	Optimal	Medium
Ad hoc-based	Optimal	Medium
Optinet	Optimal	High
MIRON*	Optimal	High
HIP-based	Optimal	High
S-RO	Optimal	High
SIP-based*	Optimal	High

* Handoff-aware RO Schemes

The RO schemes that are better suitable for each of the internet applications are given in Table 2. Though the degree of RO for all RO schemes is optimal the signaling overhead varies. It has three types of signaling overhead such as low, medium and high. As the real-time interactive audio and video applications cannot tolerate delay, jitter and bandwidth issues, the RO schemes that have low signaling overhead is more suitable.

As the one-to-many streaming of real-time audio and video applications moderately tolerate delay, jitter and bandwidth issues, the RO schemes that have medium signaling overhead is suitable. As the streaming of stored audio and video applications can tolerate delay, jitter and bandwidth issues more than other two previous applications, the RO schemes that have high signaling overhead is suitable. As the non-real-time applications can tolerate delay and cannot tolerate packet loss, the RO schemes that have improved handoff performance is suitable. In NEMO environment, packet losses can occur during handoff [9].

Table 2: Internet applications and its suitable RO schemes

Internet Applications	RO Schemes
Real-time interactive audio and video	• OPR • xMIPv6 • PCH-based
One-to-many streaming of real-time audio and video	• Simple Prefix Delegation • ND-proxy • Ad hoc-based
Streaming of stored audio and video applications	• Optinet • HIP-based • S-RO
Non-real-time applications	• MIRON • SIP-based

6.1. RO schemes suitable for real-time interactive audio and video applications

6.1.1. Optimal path registration (OPR)

In OPR proposed by Park et al. [19], like ND-Proxy or Ad hoc-based scheme the prefix of the foreign network is advertised inside the mobile network. The difference of OPR with ND-Proxy and Ad hoc-based schemes is that the prefix is relayed only to the MRs, resulting in movement transparency for other MNNs. To provide movement transparency, MRs translate prefix of source and destination addresses of outbound and inbound packets of its network. Movement transparency costs additional memory due to maintaining a translation table and processing cost per packet for address translation.

Signaling is low in OPR than other schemes discussed in delegation class because of not sending BUs to CNs. To compensate for not sending BU, CNs are informed of the change in translated address (like CoA in other schemes) by marking the packet's header. This costs the MR high memory due to state management to track every CN-MNN communicating pair along with additional processing overhead per packet. Kim et al. proposed a scheme that improves the performance of OPR by further reducing the number of BU [20].

6.1.2. xMIPv6

In xMIPv6, proposed by Gu et al. [21], MRs send BUs containing CoAs of MRs above it to their corresponding HAs. An MR obtains CoAs of MRs above it from the MR to which it is attached. Packets sent from the CN to an MNN reach the HA that inserts the CoAs in the header of packets. Unlike S-RO, xMIPv6 does not need BU from all MRs, resulting in the advantage of reduced signaling and smaller time for HA to get CoAs of all MRs above. Unlike other schemes in this class, packets will always go through a tunnel between an HA and the corresponding MR.

6.1.3. Path control header (PCH)-based

Na et al. [22] proposed a scheme where the CoA of the MR is inserted into packets by the corresponding HA when a packet travels from an MNN to a CN. After passing through all the HAs, the packet's header contains the CoAs of all MRs above. Path control is achieved by a specific router (between last HA and CN) that extracts the CoAs to insert in the packet's header sent from CN to MNN. Like xMIPv6, this scheme has the advantage of low signaling because of absence of BU from MRs.

Based on the above information, OPR, xMIPv6 and PCH-based schemes have degree of RO as optimal and signaling overhead as low. Comparatively, these three schemes can offer better delay, jitter and bandwidth requirements. Hence, they are suitable for real-time interactive audio and video applications as it cannot tolerate any deterioration in the above parameters.

6.2. RO Schemes suitable for one-to-many streaming of real-time audio and video applications

6.2.1. Simple prefix delegation

In Simple Prefix Delegation, proposed by Lee et al. [23], a prefix that can be aggregated at the prefix of the foreign network is hierarchically delegated to the MRs. MRs advertise the delegated prefix inside its own network using Delegated Prefix Option in the header. Since prefix is hierarchically delegated, packet forwarding inside the mobile network can be done based on prefix of packets' destination address.

This scheme, however, requires a prefix delegator in every mobile network, requiring additional overhead of performing extra functionality related to prefix delegation. Its signaling amount is proportional to number of Mobile Capable Nodes (MCN), and in between low and high (i.e. medium) amount of signaling of other schemes in this class. Memory requirement is low because only attached MRs' prefix needs to be tracked as the next hop. The advantage of the signaling not being high costs incomplete RO for LFNs whereas route for MCNs is optimal.

6.2.2. Neighbor discovery proxy (ND-Proxy)

In this scheme, proposed by Jeong et al. [24], RO is achieved by advertising the prefix of the foreign network inside the mobile network. Each MR obtains a CoA from the advertised prefix and advertises the prefix inside its mobile network. All MCNs use the advertised prefix to obtain CoAs.

Routing of packets is different from Simple prefix delegation (where prefix are hierarchically delegated) because all addresses are obtained from a single prefix. When TLMR receives a packet destined to an MNN, and the next hop for the destination is not present in the routing table, it makes a neighbor discovery query. An MR attached below responds if the MNN's CoA that is being sought is directly under the MR. Otherwise, the MR relays the search message to MRs underneath, and replies to the query when an MR underneath responds with the CoA being sought. Thus, MRs actually act as proxy for MNNs for neighbor discovery.

Routing used in ND-Proxy will introduce delay at the start of communication. Yet, it has the advantage of not requiring a prefix delegator in every mobile network. Signaling requirement is similar to that of Simple prefix delegation whereas memory requirement is little higher (hence, low instead of lower) than Simple Prefix Delegation because of maintaining routing entries for all communicating MNNs underneath an MR.

6.2.3. Ad hoc-based

In Ad hoc-based scheme proposed by Su et al. [25], like ND-Proxy, MCNs obtain CoA from the prefix of the foreign network. Unlike ND-proxy, for routing inside mobile network, the route between the MNN and the AR in foreign network is discovered using an Ad hoc protocol. Route discovery requires flooding of messages that consumes bandwidth as well as introduction of delay at the start of communication or after communication interrupted due to handoff.

Moreover, Ad hoc network protocols are intended for unstable networks, and do not take advantage of the hierarchical nature of the nested mobile networks. Since it does not optimize route for LFNs, signaling requirement is similar to Simple Prefix Delegation at the cost of higher end-to-end delay for LFNs' packets. Due to maintaining routing entry for all communicating MNNs, memory requirement is similar to ND-Proxy.

Although Ad hoc On-demand Distance Vector (AODV) is a protocol for Ad hoc networks, it was not included in delegation class under Ad hoc-based scheme due to the following reason. The basic principle used in Ad hoc-based scheme is to obtain a CoA from the foreign network prefix contrasting the obtaining of CoA from MR's prefix in the AODV-based scheme [26].

To sum up, all the RO Schemes used in one-to-many streaming of real-time audio and video applications have degree of RO as optimal and signaling overhead as medium. Comparatively, these schemes can offer delay, jitter and bandwidth requirements moderately. Hence, they are suitable for one-to-many streaming of real-time audio and video applications as it can moderately tolerate any deterioration in the above parameters.

6.3. RO schemes suitable for streaming of stored audio and video applications

6.3.1. Optimal routing for network mobility (Optinet)

Perera et al. [27] proposed an architecture called Optinet which is similar to Simple Prefix Delegation but with different prefix delegation procedure. Unlike Simple Prefix Delegation, a DHCP client in an MR obtains a prefix from the network it attaches to (a mobile network or a wired network). Petander et al. [28] extended Optinet (xOptinet) that reduces signaling by restricting the obtaining of the CoAs to only those nodes that are actively communicating with CN during handoff.

Moreover, xOptinet optimizes the route for the LFNs by having the MR perform RO signaling on behalf of attached LFNs. Unlike other schemes in delegation class, Optinet requires a DHCP client and a server at every mobile network. Moreover, LFNs' route optimization requires sending BUs to CNs, and tracking LFN-CN communications resulting in high amount of signaling and memory requirement, respectively.

6.3.2. HIP-based

A Host Identification Protocol (HIP)-based route optimization is proposed by Novaczki et al. [29], [30]. Like MRs in other schemes in delegation class, the mobile Rendezvous Servers (mRSVs) in HIP-NEMO obtain a prefix from the foreign network, and delegate parts of the prefix to attached mRSVs to advertise inside the mobile network which they are in. For route optimization, mRSV uses the prefix as location identifier of MNNs when sending location updates to CNs and RSVs (acts like HA and DNS), and translates the source/destination address of outgoing/incoming packets. When an mRSV attach to an AR, it obtains new prefix, performs location update signaling with CNs and RSVs on behalf of MNNs, and updates the prefix of the attached mRSVs that also do the same.

Location update, attaching to a mobile network and delegation of signaling to mRSVs are performed according to HIP [31]. Signaling for this scheme is the same as MIRON because of sending location updates to all CNs. Memory requirements and per packet processing overhead is like OPR because of similarity in address translation process. HIP that supports mobility and multi-homing for hosts is used for NEMO in the scheme proposed by Ylitalo et al. [32].

6.3.3. Simple route optimization (S-RO)

In S-RO, proposed by Kim et al. [33], initially the MRs send their CoAs to their respective HAs. Packets sent from CN are thus encapsulated by the HAs; MRs de-capsulate the packets, and send BUs to the source of de-capsulated packets. CN then obtains CoAs of MRs, and sends packets directly to the TLMR with the list of CoAs in the packet header. This scheme suffers from a large delay for the CN to receive all the CoAs for complete route optimization; this is especially true for higher nesting level. Sending of BUs to HAs and CN consumes large amount of signaling.

All the RO Schemes used in streaming of stored audio and video applications have degree of RO as optimal and signaling overhead as high. Comparatively, these applications can have less-sensitive delay, jitter and bandwidth requirements. Hence, the RO schemes mentioned in Section VI.C are suitable for these applications.

6.4. RO schemes suitable for non-real-time applications

6.4.1. Mobile IPv6 route optimization for NEMO (MIRON)

In MIRON, proposed by Calderon et al. [34], [35], like ND proxy, MCNs obtain the CoA from the prefix of the foreign access network. Upon attachment to an MR, an MCN obtains a CoA from MR's home prefix, and sends a BU to it's HA. The MR intercepts the BU, and notifies the MCN to obtain a new CoA using PANA [36] and DHCP. MCN sends a DHCP request to obtain a CoA. Instead of relaying the prefix (like ND-Proxy) inside the mobile network, this scheme relays the request to the DHCP server at the foreign network. Assigned CoA is then relayed back to the MCN.

Relaying is performed by DHCP client and server component in MRs. After obtaining a CoA, MR notifies the attached MCNs to obtain a CoA. This procedure of obtaining a CoA is repeated at each handoff, and takes longer time than it takes in other schemes presented in delegation class. Like xOptinet, MIRON optimizes the route for the LFNs by having the MR perform RO signaling on behalf of attached LFNs, and hence signaling and memory requirement is high.

6.4.2. Session initiation protocol (SIP)-based

Huang et al. [37], [38] proposed a SIP-based [39] RO which, unlike other schemes, uses SIP session establishment procedure to discover an optimized route prior to the start of data communication. An MNN (SIP client) sends a SIP invite request to CN (SIP client) to establish a session. SIP Home Server (acting like HA) inserts CoAs of corresponding SIP-network mobility servers (acting like MRs) into the invite request that reaches CN with CoAs of network mobility servers.

RO is achieved by CN inserting the CoAs of network mobility servers in the packets sent to the MNN. At handoff, the SIP-Network mobility server at the top sends invite request (through a SIP foreign server) to all CNs on behalf of MNNs. Sending invite requests results in high volume of signaling as well as high memory requirement due to the tracking of all SIP sessions.

All the RO Schemes used in non-real-time applications have degree of RO as optimal, signaling overhead as high and aware of handoff. Comparatively, these applications can offer better services with reduced packet loss due to handoff awareness. Hence, the RO schemes mentioned in Section VI.D are suitable for these applications.

7. Conclusion

The mobile network that supports NEMO is inevitable in mobile platforms such as car, bus, train, air-plane, etc. The use of NEMO BSP gives more benefits than MIPv6 in mobile platforms. The limitations of NEMO can be addressed by RO schemes. Though RO schemes address the problems of NEMO, ensuring QoS is great challenge in various internet applications. Among the various existing RO schemes, the suitable schemes for different kinds of internet applications are selected based on the parameters such as degree of RO, signaling overhead and packet loss.

The internet applications can be classified into real-time and non-real-time applications. The real-time applications are real-time interactive audio and video applications; one-to-many streaming of real-time audio and video applications; streaming of stored audio and video applications. The non-real time applications are file transfer, web access, e-mail, etc. As the QoS requirements for each application can vary from each other, suitable selection of existing RO schemes was done. From this survey, it is evident that most of the RO schemes are not considered all QoS parameters such as delay, jitter, bandwidth and packet loss. In future, it is necessary to concentrate on these QoS parameters. The limitations of each and every scheme can be further studied with respect to QoS requirements and QoS can be better enhanced to provide more customer satisfaction.

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