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Motivations and Scenarios for Using Multiple Interfaces and Global Addresses

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Abstract

In this document, multihoming is investigated from an end-node point of view, and not from a site point of view as the term "multihoming" is commonly understood so far. The purpose of this document is to explain the motivations for fixed and mobile nodes (hosts and routers) using multiple interfaces and the scenarios where this may end up using multiple global addresses on their interfaces. Such multihoming configurations can bring a number of benefits once appropriate support mechanisms are put in place. Interestingly, this analysis is generic, i.e. motivations and benefits of node multihoming apply to both fixed end nodes and mobile end nodes.

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1. Introduction

New equipments shipped on the market now often integrate several access technologies (both wired and wireless). The main purpose of this integration is to federate all means of communications in order to access the Internet ubiquitously (from everywhere and at any time) as no single technology can be expected to be deployed everywhere. Flows may thus be redirected from one interface to the other following the loss of connectivity or change of the network conditions in different access mediums. Besides enabling ubiquitous Interent access, integrating several access technologies also allows increased bandwidth availability and selection of the the most appropriate technology according to the type of flow or choices of the user, since each access medium has different cost, performance, bandwidth, access range, and reliability.

Once multiple accesses are offered, users may want to select the most appropriate set of network interface(s) depending on the network environment, particularly in wireless networks which are mutable and less reliable than wired networks. Users may also want to select the most appropriate interface per communication type or to combine a set of interfaces to get sufficient bandwidth.

The purpose of this document is to emphasize the goals and benefits of multihoming for fixed and mobile hosts and routers in a generic fashion, i.e. without focusing on issues pertaining to hosts, or routers, or mobility. There are other documents focusing on these. issues pertaining to site multihoming in fixed networks are discussed in [1]. Mobility issues pertaining to mobile nodes and mobile networks are respectively discussed in companion drafts [2] and [3]. Our document is targetted at IPv6, although our analysis may be applicable to IPv4 as well. The readers may refer to [4] for a description of the problem specific to Mobile IPv4.

This document is organized as follows. First, the terms used in the document are defined before illustrating the motivations by means of some scenarios in Section 3. These scenarios are then used to emphasize the goals and benefits of multihoming in Section 4. Following which, Section 5 provides an analysis of the achievable goals in two multihoming configurations, i.e. when the node either has a single interface or when it has multiple interfaces. Section 6 concludes this document with a number of generic issues that will have to be solved in order to effectively meet multihoming goals and benefits.

2. Terminology

This draft is based on the terminology defined in [5]. For the purpose of clarity, we remind the definition of interface. Terms related to multihoming are not known to be defined in existing IETF RFCs.

Interface

A node's point of attachment to a link (as defined in [5])

Multihomed Node

A node (either a host or a router) is multihomed when it has several global IPv6 addresses to choose between, i.e. in the following cases when it is either:

* multi-prefixed: multiple prefixes are advertised on the link(s) the node is attached to, or.

* multi-interfaced: the node has multiple interfaces to choose between, on the same link or not.

3. Scenarios and Motivations

The following real-life scenarios highlight the motivations for multihoming. Each scenario usually yields more than one of the goals and benefits which are later outlined in Section 4. Although most scenarios focus on wireless technologies, mobility management may not be involved (one can use wireless access at office).

3.1. Need for Ubiquitous Access to the Internet

Mona is just getting out of a meeting with customers in a building. She calls her head office. This audio communication is initiated via a private wireless local area network (WLAN) link realized over one of the available Wi-Fi hot-spots in the building. This is going to be a long call and she must attend another meeting a few minutes drive from here. She walks to a taxi stand, and boards a taxi. The audio communication is automatically transferred to the public wireless metropolitan area network (WMAN) over the Wi-Max metropolitan network deployed, with no interruption of the communication.

This scenario illustrates the need to use multiple types of access technologies in order to maintain ongoing communications when a user is moving out of the coverage area of a specific technology.

3.2. Need to Redirect Established Sessions

Oliver is in the passenger lounge waiting for his train. He uses this opportunity and the presence of a WLAN hot-spot to download the news from his favorite on-line news channel. While Oliver is downloading the news, he receives a video call over his wide area 3G cellular link. The bandwidth and traversal delay of the wide area cellular link is not adequate for high quality video-conference, so both flows (video/audio) are transferred to the WLAN link provided by the hot-spot. This transfer occurs transparently and without affecting the other active flows.

This scenario illustrates the need for a nomadic user to dynamically redirect flows from one type of access technology to another based on some user preferences or traffic requirements.

3.3. Need to Set Up Preferences

Nami works at home for a publishing company using her connection to the Internet via a low-speed dial up connection, a public and unrealiable 802.11b WLAN from the street and her 3G cellular phone. Since the public WLAN is not secure, and the dial-up connection too slow, Nami checks her company's email using her 3G phone even though it is expensive. The WLAN service is used for non-confidential activities, such as web-browsing and video-conferencing, and the dial-up connection is moslty used to transmit her completed work securely and synchronizing her file system.

This scenario illustrates the need in a fixed environment to simultaneously use multiple access technologies and to select the most appropriate one according to user preferences. No assumptions are made whether flows need to be redirected or not from one access technology to another. These preferences can be dynamic (e.g. the WLAN link is only used if the signal is good and there is no unusual latency) or configured once for each application (e.g. applications exchanging confidential data always over the most secure link).

3.4. Need to Select the Best Access Technology

Alice is a paramedic. Her ambulance is called to the scene of a car accident. She initiates a communication to a hospital via a wide area cellular link for the relay of low bit-rate live video from the site of the crash to assess the severity of the accident. It is identified that one of the passengers has suffered a severe head injury. Alice decides to consult a specialist via video conferencing. This session is initiated from the specialist via the same wide area cellular link. Meanwhile, Alice requests for the download of the patient's medical records from the hospital servers.

The wide area cellular link is too slow for this download, so the download is transfered to the ambulance satellite link. Even though this link provides a significantly faster bit rate it has a longer traversal delay and only downlink is available. Thus, only the downstream of the download is transferred while upstream proceeds over the wide area cellular link. Connectivity between the parametic and the ambulance is managed over a WLAN link. Even though Alice has performed a partial hand-off for the transfer of the downstream to the satellite link, the upstream and the video conferencing session remains on the wide area cellular link. This serves best the time constraint requirements of the real time communications.

This scenario illustrates the need in a mobile environment for both ubiquitous access to the Internet using whatever available interface and the need to dispatch flows to particular access media according to traffic characteristics or preferences. It also illustrates that flows can be directed to separate media downlink and uplink. The fact that the actual connection to the Internet is maintained via the ambulance to which the paramedic is connected to via a WLAN link illustrates to need to express preferences on the path to be taken from a remote computer (i.e. a mobile router in the ambulance in this case).

3.5. Need to Dispatch Traffic over Distinct Paths

Max drives his car and constantly keeps some sort of Internet connectivity through one of the many available access technologies solely managed by a dedicated on-board unit (OBU). Data are further transmitted to other on-board units. His car navigator downloads road information from the Internet and his car-audio plays on-line audio streaming while data collected by sensors is transmitted to the car manufacturer (e.g. consumption, engine pressure) and safety data is exchanged between surrounding vehicles (e.g. geographic position, speed, brakes on/off, accident alerts). Toll bills are paid automatically and displayed on his navigation screen, while road sign transmit information (speed limitation, traffic lights).

When his car passes an area where only a wide coverage-range cellular network is available, safety related sessions are maintained via the cellular network whereas infotainment data is buffered and transmitted over high data rate network access when one becomes available. Toll bills and road sign data are transmitted over a dedicated radio interface, whereas data exchanged between vehicles is transmitted over a preferred media. Time-critical safety sessions are always given priority.

This scenario illustrates the applicability of multihoming in road transportation and emphasizes more particularly the need to

prioritize traffic transiting in a particular access network when there is a possibility to send data over an alternative route. The availability of multiple access medium and the variety of on-board units illustrates a NEMO [6] scenario as currently considered in the CALM Architecture [7] designed by ISO TC204 WG16 for Intelligent Transportations Systems (ITS) [8]. The exchange of safety data illustrates the ongoing work of the car-to-car communication consortium (C2C-CC) [9].

3.6. Need for Reliability

Ingrid, a doctor, performs an operation via long-distance medical system. She watches a patient in a battle field over the screen which delivers real-time images of the patient. Sensors on her arms deliver her operational actions and a robot performs the actual operation in the battle field. Since the operation is critical, the delivery of patient images and Dr. Ingrid's action is done by bi-casting from/to multiple interfaces bound to a distinct technology or distinct radio range. So in case packets are delayed or one of the interface fails to maintain connectivity to the network, her distant operation can be continued.

This scenario illustrates the need to use multiple access technologies in order to improve reliability upon failure of one of the access technologies.

3.7. Need to Accelerate Transmission

Roku is at the airport waiting to board the plane. She receives a call from her husband. This audio communication is received via a WLAN link realized over one of the available hot-spots. She knows this is going to be a long flight and wishes to catch up on some work. Roku uses a WLAN connection to download the necessary data. However, there is not enough time before boarding and she decides to accelerate the download. Her notebook is equipped with an additional WLAN interface. This additional WLAN interface is then used to connect to another access point, and the different download flows are distributed between the two wireless interfaces.

This scenario illustrates the need to use multiple accesses to the Internet in order to accelerate the amount of data that could be transmitted over a period of time.

4. Goals and Benefits of Multihoming

From the scenarios presented in the previous section, we can highlight the goals and benefits of node multihoming. The goals cannot really be distinguished from the benefits, but there are several situations where multihomed is either advisable or beneficial. These benefits and goals listed here are by no means distinct and separate; most of them overlap with one another. It is not the objective here to classify the benefits and goals into different non-overlapping consituents. Instead the objective is to list the possible benefits and goals different people have in mind when deploying a multihomed node.

Goals	Scenarios 1	2	3	4	5	6	7
Ubiquitous Access	o			o	o		
Flow Redirection	o	o	o	o	o		
Reliability			o	o	o	o	
Load Sharing					o		
Load Balancing			o	o			o
Preference Settings		o	o	o			
Aggregate Bandwidth				o			o
Usage: F=Fixed N=Nomadic M=Mobile	M	N	F	M	M	F	N

Figure 1: Goals Applying to Each Scenario

Figure 1 summarizes which goal applies to the scenarios introduced in Section 3. Note that all these goals and benefits apply to both fixed end nodes and mobile end nodes, though the scenarios may either focus on a fixed used (F), or nomadic usage (N), or a mobile usage (M). Nomadic and mobile users are both on the move, while a fixed user doesn't physically move. The difference between nomadic usages and mobile usages is that sessions are not required to be maintained when the access network is changed as a result of physical move within the topology. No assumptions are made whether mobility support mechanims may be useful or not in any of the fixed, nomadic and mobile usages in order to maintain sessions. This is out of

scope of the present document.

4.1. Permanent and Ubiquitous Access

To provide an extended coverage area via distinct access technologies.

Multiple interfaces bound to distinct technologies can be used to ensure a permanent connectivity is offered, anywhere, anytime, with anyone.

4.2. Reliability

To act upon failure at one point of attachment, i.e. the functions of a system component (e.g. interface, access network) are assumed by secondary system components when the primary component becomes unavailable (e.g. failure). Connectivity is guaranteed as long as at least one connection to the Internet is maintained.

A potential means is to duplicate network component, another is to duplicate a particular flow simultaneously through different routes. This minimizes packet loss typically for real-time communication and burst traffic. It also minimizes delay of packet delivery caused by congestion and achieves more reliable real-time communication than single-casting. For mobile computing, bi-casting avoids dropping packets when a mobile node changes its interface during communication [10].

4.3. Flow Redirection

To be able to redirect flows from one interface (or address) to another without having to re-initiate the flow. This can be due to preference changes or upon network failure.

4.4. Load Sharing

To spread network traffic load among several routes. This is achieved when traffic load is distributed among different connections between the node and the Internet [11].

4.5. Load Balancing/Flow Distribution

To separate a flow between multiple points of attachment (simultaneously active or not) of a node, usually chosing the less loaded connection or according to preferences on the mapping between flows and interfaces.

4.6. Preference Settings

This goal is to provide the user, the application or the ISP the ability to choose the preferred transmission technology or access network based on cost, efficiency, policies, bandwidth requirement, delay, etc.

4.7. Aggregate Bandwidth

This goal is to provide the user or the application with more bandwidth.

Bandwidth available to the user or the application may be limited by the underlying technology (e.g. GSM has scarce bandwidth) or by some policies (e.g. monthly rate paid by the user). Multiple interfaces connected to different links or ISPs can increase the total bandwidth available to the user or application.

5. Analysis

From the definition of a multihomed node it follows that a multihomed node has several IPv6 addresses to choose between. In order to expose the goals and benefits in managing multihomed nodes, we propose to distinguish two main cases: either the node has only one interface, or the node has several interfaces. In the former case, the node is multihomed when multilpe prefixes are advertised on the link the node is attached to. This distinction is important and sometimes subtle but the implications are important.

5.1. Case 1: One Interface, Multiple Prefixes

The single-interfaced node is multihomed when several prefixes are advertised on its interface. The node must therefore configure several IPv6 addresses.

A typical example is a node with a 802.11b interface, connected to an access point. The access point is connected trough an Ethernet link to two access routers. Each access router is configured to advertise distinct network prefixes by Router Advertisements on the link and can be used as default router. Several reasons may lead to configure two access routers on the same link: for instance, the access points may be shared between different ISPs, or two access routers may be used for redundancy or load sharing purposes. The node will then build two global IPv6 addresses on its interface.

We now analyse which of the goals detailed in Section 4 can be met with this configuration.

- Ubiquitous Access: NO

  Ubiquitous access cannot be guaranteed when the node loses Internet connectivity through its sole interface (e.g. the node is going outside the coverage area of its access point).

- Flow redirection: YES

  The node might need to redirect a flow from one address to another for several reasons. For example, if one of the IPv6 prefix becomes unavailable, flows using the address from this prefix could be redirected to the address obtained on the other prefix.

- Reliability: MAYBE

  In case of failure of one IPv6 prefix, one of the address of the node will not be valid anymore. Another available address built from other prefixes may allow the node to recover this sort of failure. Bi-casting can be performed to ensure the delivery of packets on the node. To do so, more than one IPv6 address must be used simultaneously for one flow. Bi-casting would allow the node to seamlessly change the address used on the node.

- Load sharing: YES

  Load Sharing can be performed in the network, according to the address used by the node. The choice of the address used by the node and the router selection can be influenced by load sharing rules. This mostly benefits the network side: if different access routers or routes can be used to forward the node's traffic, the traffic load will be shared in the network.

- Load balancing/Flow Distribution: NO

  Load balancing cannot be performed when the node has only one interface.

- Preferences: YES

  The source address can be chosen according to preferences set up by the user, or according to preferences set up in the network (such as with the default router preferences option introduced in Router Advertisement [12]), or by the ISP.

- Aggregated Bandwidth: MAYBE

  With only one interface connected to a link, the node generally will not be able to benefit from an increased aggregated bandwidth

with multiple prefixes. However, this benefit might be gained indirectly. For instance, by alternating between different addresses, the total throughput may be higher (eg. due to load sharing). Also, some web and file transfer servers limit transfer bandwidths based on the client's address. By using different addresses to connect to the same server, the node may also see an increase in file transfer rate.

5.2. Case 2: Several Interfaces

In this case, the node may use its multiple interfaces either alternatively or simultaneously. If used simultaneously, the node uses several IPv6 addresses at the same time (at least one address per interface, or several if several prefixes are announced on the link(s) it is connected to). If used alternatively, the node may switch between its interfaces (e.g, one at a time), which is the case described above in Section 5.1. In the paragraphs below, we assume that multiple interfaces are used simultaneously. We also note that multiple interfaces can be connected to the same link as well as to different links. These configurations will imply different issues. All these multihomed configurations may yield different benefits to the node.

A typical example is a node with two interfaces, each one on a different technology (e.g. a WLAN 802.11b interface and a 3GPP GPRS interface), in order to benefit from a better coverage area and the characteristics of each technology.

We now analyse how each of the goals listed in Section 4 can be met with such multihomed configuration:

o Ubiquitous Access: MAYBE

  It is easier to guarantee ubiquitous access when the node has multiple interfaces since distinct technologies may be available at a given time according to the location and administrative policies.

o Flow redirection: YES

  In case of a change in user preferences, or a failure, flows might need to be redirected from one interface to another one. Flows can be redirected individually or all flows attached to an interface might be redirected at once.

o Reliability: YES

  Two levels of redundancy can be seen in this case: either one

address of one interface is not valid anymore (e.g. because the corresponding prefix is not advertised on the link), or the node loses its internet connectivity through one interface. In the former case, another IPv6 address available on the interface would allow the node to switch addresses for on-going flows. In the latter case, another connection to the internet through another interface would allow it to redirect on-going flow from the previous interface to the new one. In either cases the node needs to change the IPv6 address for on-going sessions from the no longer valid address to one of the address available on the target interface. The redirection will trigger a decision process to choose the best target interface to redirect the flow to.

Bi-casting might be used to ensure the packets delivery on the node. It would also allow seamless redirection between two addresses / interfaces with zero packets loss. Bi-casting can be performed if several IPv6 addresses can be simultaneously used for one flow. One entity between the CN (included) and the node (excluded) must duplicate the traffic to the destination node.

o Load Sharing: YES

This benefit is mainly for the network side: if different access routers or routes can be used to forward traffic going into and out of the node, they can share the traffic load on the network. If the node uses several addresses at the same time for its on-going sessions, load sharing can be performed in the network. This goal can be a parameter that helps the source address selection.

o Load balancing/Flow Distribution: YES

Load balancing can be achieved on the node if several interfaces are used simultaneously. Several interfaces can be used to spread the traffic load on the node. This implies the choice of the IPv6 address to use for each flow and the ability to choose a different address for each flow.

o Preferences: YES

Interface and address selection is required. The problem can be seen exactly as in the first case (the node has only one interface) if we consider that the interface preference is a parameter for the address selection. Therefore in this case, the interface selection/preference is a supplementary parameter in the address selection algorithm.

o Aggregated Bandwidth: YES

With multiple interfaces connected to different links, the node generally will be able to benefit from an increased aggregated bandwidth.

6. Issues

In this section, we attempt to list a number of generic issues that will have to be solved in order to meet the multihoming goals.

Figure 2 summarizes which issues apply to which case detailed in the previous section (availability of a single interface or multiple interfaces). The sign '+', '-' or '=' indicates if the issue is more important, less important, or equally important to solve for the case under consideration

Issues	Cases (1)	Cases (2)
Source Address Selection	o =	o =
Recovery Delay	o	o +
Change of Traffic Characteristics	o -	o +
Transparency	o +	o +

Figure 2: Issues and their Importance for Each Case

6.1. Address Selection

The multihomed node has several addresses, which implies the appropriate address must be chosen when an IPv6 communication is established (e.g. when a TCP connection is opened). An address selection mechanism is therefore needed.

The choice of the address can be influenced by many parameters: user preferences, ingress filtering, preference flag in Router Advertisement, destination prefix, type of interface, link characteristics, etc.

6.2. Failure Discovery and Recovery Delay

A particular access to the Internet may become unavailable while it is being used. The time needed for detecting an address has become invalid and the time to redirect communications to one of its other addresses is considered critical. Efficient failure detection and recovery mechanisms are therefore required.

Note that transport sessions with multihoming capabilities such as SCTP [13] may be able to continue easily since SCTP has built-in transmission rate control mechanims to take into account the differences between two paths.

6.3. Change of Traffic Characteristics

The change of path for a specific session (e.g. due to change of interface) may cause changes on the end-to-end path characteristics (higher delay, different MTUs, etc). This could have an impact on upper layer protocols such as transport protocols (particularly TCP) or applications that are sensitive to changes.

6.4. Transparency

In some situations, it will be necessary to divert some or all of the sessions from one interface or prefix to another (e.g. due to loss of network connection or the access router becoming unreachable - this could be particularly frequent for mobile nodes). With no support mechanism, an address change would cause on-going sessions using the invalid former address to terminate, and to be restarted using the new address. To avoid this, a recovery mechanism allowing the redirection of all current communications to one of the other IPv6 addresses is needed.

In the case of a mobile node changing its point of attachment using the same interface, all flows must be redirected to the new location in order to maintain sessions. A mobility management solution may be required, such as Mobile IPv6 [14] for mobile hosts or NEMO Basic Support [6] for mobile routers. Additional mechanisms may be needed if the node was using several addresses on its previous link, such as which flows shall be to redirected, which address must be associated with the new address(es). The scalability of the operations involved in the redirection of flows may also be an issue, if we consider that the node had several addresses on the previous link and several flows and/or correspondents. Issues pertaining to Mobile IPv6 and NEMO Basic Support are explained in companion drafts [2] and [3] respectively.

7. Conclusion

In this document we studied multihoming at the level of an end node. A node is multihomed in a situation where it has multiple addresses, usually due to the availability of multiple interfaces on the node, or the announcement of multiple prefixes on the link the node is attached to. This satisfies a number of needs and brings a number of potential benefits. The availability of multiple addresses allows the use of an alternate address as the replacement of another (permanent and ubiquitous access to the Internet, reliability) or the transmission of multiple flows simultaneously over different routes (flow redirection, load sharing, load balancing/flow distribution, preference settings or aggregate bandwidth).

This study is motivated for both fixed nodes and mobile nodes, but the motivation prevails for mobile nodes (hosts and routers). The benefits of multihoming can only be achieved once some issues are solved. Generic issues were outlined in the present document, whereas issues specific to mobile hosts and mobile routers are investigated in the associated documents [2] and [3] and, respectively.

8. Contributors

This document is based on an earlier document to which Thomas Noel (ULP, Strasbourg) and EunKyoung Paik (SNU, Seoul) also contributed in addition to the authors listed in the present document.

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