Towards a Media Independent Handover Based Approach to Heterogeneous Network Mobility

**Enda Fallon**, **John Murphy**, **Liam Murphy**, **Yuansong Qiao**, **Xuefeng Xie**, **Austin Hanley**

---

**Abstract** — In recent years the number and diversity of networks available to mobile computing devices has increased dramatically. It is now feasible for a device to support multiple networks such as 3G, 802.3, 802.11 and even 802.16. Given the diversity of these networks in terms of range and bandwidth, there is a need to define a seamless approach to network handover. While current 802 standards provide the facility to detect and select access points, these mechanisms are specific to individual network types. Moreover, current 802 standards do not provide the facility, or even the availability, of information triggers for handover. In order to address issues relating to heterogeneous network handover, the IEEE have proposed a new standard: 802.21, also referred to as Media Independent Handover. It is proposed that the emerging 802.21 standard will enable a mobile device to detect and initiate handover from one network to another. Currently the 802.21 standard is at draft stage and no implementations are available. This paper investigates how elements of the proposed standard can be utilised in conjunction with the transport layer Stream Control Transmission Protocol (SCTP) in order to facilitate seamless network handover. We compare a pre-emptive 802.21 oriented switch strategy against standard fault reactive SCTP strategies. Results indicate that the 802.21 oriented strategy behaves more effectively than conservative SCTP switchover strategies, and has equivalent performance to aggressive SCTP switchover strategies.

**Keywords** – Media Independent Handover, 802.21, SCTP, WLAN

---

**I. Introduction**

Motivated by the pervasive deployment of wireless networks based on Wi-Fi, WiMAX and 3GPP (3rd Generation Partnership Project) standards, mobile devices are increasingly required to support multiple underlying networks. In turn the availability of multiple underlying heterogeneous networks with diverse capabilities is driving the need for seamless session continuation during network migration. The IEEE, through 802.21 [1] are addressing this requirement. 802.21 defines an approach to facilitating service transition based on triggering and providing network detection and selection assistance.

While 802.21 defines a framework for network mobility it does not define a specific network mobility protocol to implement network switchover. In this paper the transport layer Stream Control Transmission Protocol (SCTP) [2][3] has been selected to implement network mobility.

Through its support for multi-homing SCTP has the ability to maintain multiple underlying network paths in a single end to end association. At the set-up of an SCTP association, one of the IP addresses from the returned list is selected as the primary path. Data chunks are transmitted over this primary transmission path by default. The functionality of SCTP is two fold, it manages switch decisions relating to network migration as well as implementing the path switchover. The switch management functionality uses a state for each path. The state can have value “active” or “inactive”. A path is set to inactive in either of 2 scenarios (a) if a heartbeat chunk transmitted to the destination on that path was not successfully acknowledged (b) if transmission of packets on the path repeatedly fails. Both of these mechanisms are reactionary to network failure.

A feature of the 802.21 standard is its ability to predict network state changes, *link going down/link coming up*. The signal strength of a utilized wireless network facilitates this functionality. In this paper the switch management features of SCTP are disabled by setting default parameters. A switch management feature is introduced which
takes as input parameters relating to the signal strength of available wireless networks. These signal strengths are used as the basis for switch decisions. This signal strength based switch strategy is then compared against a number of SCTP based switchover strategies.

This paper is organized as follows. Section 2 details related work in the area. Section 3 provides an overview of 802.21 and SCTP. Section 4 describes in detail the SCTP path management functionality. Section 5 illustrates the simulation setup. The test results are presented in Section 6. Conclusions and future work are discussed in Section 7.

II RELATED WORK

There are a number of efforts ongoing which investigate how the performance of low layer switch strategies can be enhanced through the use of 802.21 type functionality. In [4] an integrated 802.21/SCTP based switch strategy is adopted. The performance of this strategy is assessed in a number of wired and wireless network environments. In [5] and [6] an enhanced handover mechanism utilising 802.21 type primitives are proposed for MIPv6 networks. These studies indicate that switch performance can be enhanced by removing router discovery time. In [7] an 802.21 based Universal Information service is presented which enables seamless network migration without the need for human intervention.

In [8] failover mechanisms for transport layer protocols are investigated. Results indicate that an aggressive failover strategy does not degrade performance and often improves the data throughput to utilising applications. These findings have particular significance for this investigation.

Other efforts investigate how the SCTP based switchover strategies can be enhanced. In [9] it is suggested that the SCTP handover strategy is reactive in nature and a more proactive approach where handover is based on path delays should be introduced in order to pre-empt and avoid path failures. In [10] an SCTP handover scheme for Voice over IP (VoIP) applications for heterogeneous networks is presented. The proposed handover scheme is based on the ITU-T E-Model for voice quality. In [11] performance of SCTP handover is investigated and a new heart beat mechanism is suggested.

III TECHNOLOGY OVERVIEW

a) Media Independent Handover

802.21, also known as Media Independent Handover (MIH) is an emerging IEEE standard which supports seamless handover between homogenous and heterogeneous networks. 802.21 does not in itself implement network handover, rather it provides information to allow handover to and from a range of networks including cellular, GSM, GPRS, WiFi, Bluetooth. The network handover enabling function within the protocol is implemented through the MIH function. The MIH function consists of 3 elements, the event service, command service and information service.

Media Independent Event Service

The event service will typically be used to detect need for handovers. For example an indication that the link will cease to carry MAC SDUs at some point in the near future. This has the potential to reduce the time taken to handover between attachment points.

Table 1 below is a subset of the proposed events for the 802.21 event service [1]. Event 3 will provide higher layers with a predictive indication of network degradation. Internally 802.21 uses signal strength as an indicator of imminent link failure.

<table>
<thead>
<tr>
<th>Event Id</th>
<th>Event Type</th>
<th>Event Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>State Change</td>
<td>Link Up</td>
<td>L2 connection has been established</td>
</tr>
<tr>
<td>2</td>
<td>State Change</td>
<td>Link Down</td>
<td>L2 connection has been broken</td>
</tr>
<tr>
<td>3</td>
<td>Predictive</td>
<td>Link Going Down</td>
<td>L2 connection loss is imminent</td>
</tr>
</tbody>
</table>

Table 1: 802.21 Event Service – Event List

Media Independent Command Service

The command service enables higher layers, locally or remotely, to control the physical, data link and logical link layers. The higher layers control the reconfiguration or selection of an appropriate link through a set of handover commands. The commands carry the upper layer decisions to the lower layers. For example the command service may be used to request a mobile node to switch between links. Commands defined include MIH_Switch, MIH_Get_Status, etc.

Media Independent Information Service

Media Independent Information Service (MIIS) provides a framework and corresponding mechanisms by which a MIHF (Media Independent Handover Function) entity may discover and obtain network information existing within a geographical area to facilitate the handovers. MIIS primarily provides a set of information elements (IEs), the information structure and its representation and a query/response type of mechanism for information transfer. This contrasts with the asynchronous push
model of information transfer for the event service. The information may be present in some information server from where the MIH Function in the station may access it.

b) Stream Control Transmission Protocol
Stream Control Transmission Protocol (SCTP) is an IP transport protocol, existing at an equivalent level with UDP and TCP, which was originally designed as a general-purpose transport protocol for signalling data. While SCTP and TCP are both Connection-Orientated Protocols and therefore share many characteristics there are also two fundamental differences:

Multi-homing
SCTP permits the endpoints to communicate with each other through multiple IP addresses. SCTP uses the term association to describe the connection between two SCTP endpoints. An association is identified by the transport addresses of both SCTP endpoints. Each SCTP endpoint provides a list of transport addresses which include the IP addresses of the endpoint and an SCTP port to its peer at the startup stage. SCTP supports link backup for multi-homed endpoint through this built-in multi-homing feature. Data is transmitted on the primary path. Data retransmission is performed on backup path. After the primary path failure is detected, data will be sent on the backup path.

Multi-streaming
SCTP permits a user to send data with multiple streams in one association. The streams are independent of each other. This mechanism avoids head-of-line blocking between streams. The data of each stream can be delivered to the user in sequence or in the order of arrival.

The multi-streaming feature of SCTP facilitates an application to establish multiple connections with its peer rapidly. Some applications can improve their transmission efficiency with the capability of classifying data and sending different types of data in different streams. Such as for a real-time streaming application, RTP and RTCP can be transmitted in different streams. Each layer of a hierarchy codec can also be encapsulated in a separate stream.

IV SCTP PATH MANAGEMENT
a) Summary of SCTP parameters
The SCTP parameters which are used to implement the switch over management strategy are:

- **Path.Max.Retrans** – the path retransmission limit.
- **SACK delay** – the maximum time the receiver waits before an acknowledgement for a chunk is sent.
- **HB.interval** – the interval at which heartbeats are sent to monitor an SCTP endpoint.

According to [2] the following protocol parameters are recommended:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommended Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTO.Initial</td>
<td>3 seconds</td>
</tr>
<tr>
<td>RTO.Min</td>
<td>1 second</td>
</tr>
<tr>
<td>RTO.Max</td>
<td>60 seconds</td>
</tr>
<tr>
<td>Association.Max.Retrans</td>
<td>10 attempts</td>
</tr>
<tr>
<td>Path.Max.Retrans</td>
<td>5 attempts</td>
</tr>
<tr>
<td>HB.interval</td>
<td>30 seconds</td>
</tr>
</tbody>
</table>

b) Path Handover
SCTP identifies a path by the IP address of the destination. During the protocol startup stage, each SCTP endpoint selects one of its peer’s IP addresses as a primary path for data transmission. When the primary path fails, a backup path will be selected as primary path. SCTP sends heartbeat packets periodically to an idle address to detect the reachability of the address. SCTP defines “idle address” as: no data chunks are sent within the current heartbeat interval. An address is considered active if the sender received the expected acknowledgement from its peer within a designated period. Otherwise, if the number of consecutive transmission timeouts exceeds the protocol parameter Path.Max.Retrans, it means the address is inactive. If this inactive address is current primary path, a handover will occur.

c) Calculation of Retransmission Time-Out (RTO)
If an SCTP sender can not receive a response for an SCTP data chunk from its receiver within the time of Retransmission Time-Out (RTO), the sender will consider this data chunk lost. If the number of data loss exceeds the SCTP parameter Path.Max.Retrans, the address will be marked as inactive by the sender. Therefore, RTO is a very important factor for handover and the stability of the protocol. RTO is calculated for each destination address separately based on the Smoothed Round-Trip Time (SRTT) and Round-Trip Time Variation (RTTVAR) of the path. It is initialized with RTO.Initial which is an SCTP parameter and can be configured by the user:

\[
RTO = RTO\.Initial \quad (3.1)
\]

SRTT and RTTVAR of a path are calculated by the measurement of Round-Trip Time (RTT) of the
path. The RTT measurement for a path is made for every round trip. When SCTP gets the first measurement of RTT: RTT.1st, SRTT and RTTVAR are initialized as:

\[ SRTT = RTT.1st \]
\[ RTTVAR = \frac{RTT.1st}{2} \]

(3.2) \hspace{1cm} (3.3)

And RTO is updated to:

\[ RTO = SRTT + 4 \times RTTVAR \]

(3.4)

For each time SCTP gets a new measurement of RTT: RTT.new, SRTT and RTTVAR will be updated as follows:

\[ RTTVAR_{\text{new}} = (1-\beta) \times RTTVAR_{\text{old}} + \beta \times (SRTT_{\text{old}} - RTT_{\text{new}}) \]

(3.5)

\[ SRTT_{\text{new}} = (1-\alpha) \times SRTT_{\text{old}} + \alpha \times RTT_{\text{new}} \]

(3.6)

Where \( \beta \) and \( \alpha \) are constants and their recommended values are 1/4 and 1/8 respectively. Then the new RTO is:

\[ RTO = RTO_{\text{old}} + 4 \times RTTVAR_{\text{new}} \]

(3.7)

If the new RTO is less than RTO.Min, it will be set to RTO.Min. If the new RTO is greater than RTO.Max, it will be set to RTO.Max. Every time a transmission timeout occurs for an address, the RTO for this address will be doubled:

\[ RTO = RTO \times 2 \]

(3.8)

And if the new RTO is greater than RTO.Max, RTO.Max will be used for the new RTO.

If the sender gets a response from the receiver and a new RTT is measured, SCTP will use this new RTT to calculate RTTVAR, SRTT and finally RTO by the equations (3.5) to (3.7).

V. TEST SETUP

Two Laptops, Laptop 1 representing a mobile client and Laptop 2 a back end server are connected via two 802.11g access points. The application client was hosted by a Dell D820 laptop which was multi-homed through an internal Dell Wireless 802.11g WLAN card together with an external Belkin 802.11g wireless card. An additional ZyDas USB WLAN interface provided the facility to monitor signal strength independently of the communication path. The actual monitoring of signal strength was implemented by Network Stumbler.

The server was hosted by a Dell D800 laptop. The client and server were networked by 2 Linksys WRT54GL 802.11g access points. The access point firmware was upgraded to HyperWRT which supports signal strength alteration. The access points were located 60 metres apart.

The internal wireless card on the client laptop was configured with IP address 192.168.2.109 while the external Belkin wireless card was configured with 192.168.1.115. On the server-side 2 Ethernet connections were configured. Ethernet connection 1 was configured with IP address 192.168.2.150 while Ethernet connection 2 was configured with 192.168.1.112. This configuration is illustrated in Figure 1.

All IP addresses were statically configured to ensure that 2 distinct paths were created. This avoided a situation where both wireless connections on the client were routed through a single access point (a single point of failure). The SCTP paths were as follows:

192.168.1.115-----SCTP Path 1-----192.168.1.112
and
192.168.2.109-----SCTP Path 2-----192.168.2.150

VI. TEST RESULTS

The agressiveness of switchover for an SCTP session can be configured through the Path.Max Retrans (PMR) parameter. According to [2] RTO.Max should be set to 60 seconds and the PMR value set to 5. Using this value for PMR together with (3.8), which doubles the RTO every time a transmission timeout occurs, results in a delay of \( 1+2+4+8+16+32 = 63 \) seconds before handover occurs. Previous investigations [8] have suggested that this value is excessively large. For this reason 3 test groupings were selected for evaluation:

- SCTP switchover with PMR =3 – this was considered a fault reactive, moderately aggressive switch strategy
- SCTP switchover with PMR =1 – this strategy is fault reactive yet aggressive when faults occur
- Switch over based on the strongest signal strength received by the mobile device – this strategy was predictive with regard to network failure
Each test was initiated with Path 1 (192.168.1.115 - 192.168.1.112) as primary. Each test started adjacent to access point 2 (which hosted the primary path). The mobile node then moved at slow walking pace directly towards access point 1 (which hosted the secondary path). Figures 2-4 illustrate the average signal strength as perceived by the mobile device for each group of tests from each access point.

For PMR = 3 no switchover occurred within the test duration. With PMR = 1 the switchover occurred on average after 54.75 seconds and for the strongest signal based approach the switchover occurred on average after 24.2 seconds.

Figures 5-7 illustrate the average number of outstanding bytes per second for each test group. While figures 8-10 correspond to figures 5-7 and illustrate the average number of packet retransmissions per second.

Figure 11 illustrates the accumulated number of packet retransmissions for each of the test groups. It illustrates that the predictive signal strength based switch strategy is significantly more effective than the fault reactive switch strategy where PMR = 3. The PMR = 3 strategy has an accumulated packet retransmission rate of 134642 while the strongest signal based strategy has an accumulated packet retransmission rate of 65569. However the aggressive switchover strategy with PMR = 1 has an equivalent performance to the signal based strategy. With PMR = 1 the number of accumulated packet retransmissions was 60,830.

In figure 12 the accumulated number of outstanding bytes for each switch strategy are illustrated. Again the signal strength based switchover strategy out performs the reactive PMR = 3 strategy. The strongest signal based approach has an accumulated number of outstanding bytes of 2,218,338 while the PMR = 3 strategy has an accumulated number of outstanding bytes of 4,297,731. Again however, the results show that the strongest signal based approach has an equivalent performance to the aggressive PMR = 1 based strategy. The PMR = 1 based strategy had an accumulated outstanding byte total of 2,300,375.

VI CONCLUSIONS AND FUTURE WORK
Through the use of switch parameters such as Path.Max.Retrans the aggressiveness of an SCTP switchover strategy can be altered. By selecting a low PMR value a fault intolerant strategy results.

This paper compared 2 fault reactive SCTP switch strategies with PMR = 3 and PMR = 1 respectively, against a fault predictive switch strategy based solely on received signal strength. Results indicated that the signal strength based strategy had significantly better performance than the PMR = 3 based strategy yet the performance was roughly equivalent to the aggressive PMR = 1 strategy.

Future work will investigate how additional predictive elements of the emerging 802.21 specification, such as link speed, can be utilised to enhance switchover performance.

VII REFERENCES