Intersystem Vertical handover Switching Time analysis in heterogeneous wireless networks

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Outline

• Heterogeneous networks (HetNet)
• WLAN-LTE VHO Procedure Design
• Mathematical Modelling of VHO Procedure
• Numerical analysis
• Further research
Focus: Heterogeneity and Heterogeneous Networks

• Heterogeneity covers different functional level of future networks: mobility support, seamless connection/roaming, security and packet routing.

• Ubiquity of HetNet is an integration and cooperation between different radio access networks or network elements.

• User-centric policy is more preferable than Network-centric policy in the context of HetNet and Internet of Thing.
Heterogeneous Network Slices: Internet of Things Can Access All Infrastructure Resources With Multi-Mode Terminal

“...network slices as end-to-end (E2E) logical networks running on a common underlying (physical or virtual) network, mutually isolated, with independent control and management, which can be created on demand...”

Heterogeneous Networks and Handover Types

Horizontal handover – homogeneous network;
Vertical handover - heterogeneous network;

The aim of our research:
1) Full VHO procedure with authorization, authentication, re-connection and de-registration.
2) Sojourn VHO time estimation.

Fig. 1. Architecture for WLAN – LTE VHO
Common-Use VHO Signaling Exchange Model

- Connection means physical connection
- Care of IP address means IP seamless (IP in current network = IP in target network)
- Without care of Address means IP non-seamless (new IP-address in target network)
Background and Related Works: VHO architecture, principles and scenarios

3GPP, IEEE & IETF documents

Background and Related Works:
architecture, principles and scenarios

VHO architecture, principles and scenarios


VHO estimation data


WLAN-LTE VHO procedure design

Tasks:

1. Complicated VHO procedure as a sequence of signaling messages.
2. Vertical handover time estimation method for VHO procedure.
3. Numerical analysis for VHO.

Fig. 2. Architecture for WLAN – LTE VHO
WLAN-LTE VHO procedure design.

Phase A and B

Fig. 3. WLAN – LTE VHO Procedure
WLAN-LTE VHO procedure design.

Phase C

VHO Procedure includes
- 9 functional entities
  - I - UE
  - II - ANDSF
  - III - ePDG
  - IV - eNB
  - V - MME
  - VI - S-GW
  - VII - P-GW
  - VIII - hPCRF
  - IX - HSS / AAA

and 40 signaling messages

Phase C

Fig. 4: WLAN – LTE VHO Procedure
**Mathematical modelling of VHO procedure**

Approximate method for sojourn time quantile estimation in multistage queueing system with background traffic

![Diagram of the VHO procedure](image)

- **Foreground traffic**
- **Background traffic**

\[ K = 39. \]

\[ b_k - \text{mean service time of the foreground customers,} \]
\[ d_k - \text{mean service time of the background customers,} \]
\[ \lambda_0 - \text{arrival rate of the foreground customers,} \]
\[ \lambda_k - \text{arrival rate of the background customers,} \]
\[ \rho_k = \lambda_0 b_k + \lambda_k d_k - \text{load of intensity,} \]

Coefficient of variation of the waiting time:

\[
C_k^2 = \left( \frac{\lambda_0 + \lambda_k}{\lambda_0 b_k^{(1)} + \lambda_k d_k^{(1)}} \right)^2 - 1, \quad k = 1, K. \quad (1)
\]
Approximate method for sojourn time quantile estimation in multistage queueing system with background traffic

Sojourn waiting time at $k$-stage:

$$\omega_k = \frac{\rho_k^2 \left(1 + C_k^2\right)}{2(\lambda_0 + \lambda_k)(1 - \rho_k)}, \quad k = 1, \ldots, K. \quad (2)$$

Sojourn VHO time:

$$\Delta = \sum_{k=1}^{K} (\omega_k + b_k). \quad (3)$$

Quantile level $\psi$ of a VHO time:

$$Q_\psi \approx q_\psi + \sum_{k=1}^{K} \left( \frac{\ln(\gamma_k \omega_k)}{\gamma_k} + b_k \right), \quad (4)$$

where $q_\psi$ is the unique positive root of equation

$$1 - \psi = \sum_{k=1}^{K} e^{-\gamma_k q_\psi} \frac{(\gamma_k q_\psi)^k}{k!}. \quad (5)$$
### Numerical Experiment. Average Service Time

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Average service time, ms</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I - UE</td>
<td>77.5 for (24)</td>
<td>(Nikaem and Krco, 2011)</td>
</tr>
<tr>
<td></td>
<td>28.5 for (26)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 for other steps</td>
<td></td>
</tr>
<tr>
<td>II - ANDSF</td>
<td>70</td>
<td>(estimated as HSS/ AAA)</td>
</tr>
<tr>
<td>III - ePDG</td>
<td>2</td>
<td>(estimated as P-GW)</td>
</tr>
<tr>
<td>IV - eNB</td>
<td>4</td>
<td>(Cardona, et al., 2013)</td>
</tr>
<tr>
<td>V - MME</td>
<td>15 for (27)</td>
<td>(Cardona, et al., 2013)</td>
</tr>
<tr>
<td></td>
<td>1 for other steps</td>
<td>(Prados-Garzon et. al, 2015)</td>
</tr>
<tr>
<td>VI - S-GW</td>
<td>2</td>
<td>(Nikaem and Krco, 2011)</td>
</tr>
<tr>
<td>VII - P-GW</td>
<td>2</td>
<td>(Nikaem and Krco, 2011)</td>
</tr>
<tr>
<td>VIII - hPCRF</td>
<td>70</td>
<td>(estimation as HSS / AAA)</td>
</tr>
<tr>
<td>IX - HSS / AAA</td>
<td>70</td>
<td>(Granlund et. al., 2015)</td>
</tr>
</tbody>
</table>
Numerical Example. Approximate method for VHO time quantile estimation in multistage queueing system with background traffic

Fig. 5. VHO time estimation
Numerical Example. Approximate method for sojourn time quantile estimation in multistage queueing system with background traffic.

Sojourn VHO time

95% quantile

(a) \( d_k = 10 \); (b) \( d_k = 20 \); (c) \( d_k = 50 \).

Fig. 6. VHO time estimation.
Conclusion and Further research:

1. We developed a mathematical model for vertical handover estimation as a queueing network.
2. We recommend approximate method for sojourn VHO time and its quantile estimation using multistage queueing network model with background traffic.
3. This method of sojourn time quantile estimation in multistage queueing system has following advantages:
   • possibility of sojourn time cumulative distribution function calculation,
   • method of sojourn time quantile estimation,
   • accuracy of estimation as compared with the simulation model (<7%).
4. The aim of our further research is the scheme of a VHO from a LTE network to WLAN will be discussed.