A New Approach for Vertical Handover between LTE and WLAN Based on Fuzzy Logic and Graph Theory

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Introduction

- Today, two major wireless technologies exist, LTE and WLAN.
- Greatest challenge is to decide which one to use when both are available.
- Process of moving a device from LTE to WLAN network is called vertical handover.
- Many factors could impact the handover decision, and a lot of algorithms exist with their advantages and disadvantages.

Introduction

- Here, a new algorithm is proposed which is based on fuzzy logic and a new combination of input factors.
- Also, a large number of vertical handovers could produce ping-pong effect and reduce user performance.
- According to this, a new solution for reducing ping-pong effect is proposed. A solution is based on graph theory and finding bridges in a graph.

WLAN vs. LTE

- Benefits of the WLAN are higher speed, higher bandwidth and lower price. Disadvantage of WLAN is that they provide services only on limited distances.
- In LTE and similar networks users have less speed, less bandwidth and higher prices, but they can communicate over longer distances.
- By development of both technologies, challenge was met about a decision on which network user needs to connect when both are available.

Vertical Handover

- Because many factors affect the decision (bandwidth, latency, BER (Bit Error Rate), RSS (Received Signal Strength), battery status of mobile device...), the most appropriate approach for the development of an algorithm, which would decide when to carry out the handover, are MADM (Multi Attribute Decision Making) methods, which are based on fuzzy logic.
- If the mobile device connected to a LTE network detects existing WLAN network within range, handover factor is calculated.

Vertical Handover (2)

- The collected input values are delivered in fuzzificator of Mamdani FIS editor, which transforms them into fuzzy sets on the basis of defined membership functions.
- After that, a set of IF-THEN rules is applied to get sets of decisions. Fuzzy sets of outputs are aggregated into a single set.
- Obtained set is sent to the defuzzification process. As a result of defuzzification, quantitative handover factor is obtained.
- Obtained factor determines whether a handover is required.

Vertical Handover (3)

- For input parameters of the algorithm there is no predefined combination. Combination of the following parameters has been proposed:
  - WLAN network signal strength,
  - bandwidth,
  - jitter,
  - mobile device battery status.
- Each input size is assigned to one of three fuzzy sets - low, medium or high.

IF-THEN Rules

- Number of rules should not be too big. On the other hand, it needs to cover all major input combinations. In the paper, number of rules is reduced from possible 81 (three phase values for the four possible inputs) to 8.

1. If (RSS is low) and (Bandwidth is low) and (Jitter is low) and (Battery is low) then (Handover is NO) (1)
2. If (RSS is low) and (Bandwidth is high) and (Jitter is medium) and (Battery is low) then (Handover is Probably) (1)
3. If (RSS is medium) and (Bandwidth is low) and (Jitter is low) and (Battery is low) then (Handover is Probably) (1)
4. If (RSS is medium) and (Bandwidth is high) and (Jitter is low) and (Battery is low) then (Handover is YES) (1)
5. If (RSS is medium) and (Bandwidth is medium) and (Jitter is medium) and (Battery is medium) then (Handover is YES) (1)
6. If (RSS is high) and (Bandwidth is low) and (Jitter is high) and (Battery is high) then (Handover is Probably) (1)
7. If (RSS is high) and (Bandwidth is medium) and (Jitter is medium) and (Battery is medium) then (Handover is YES) (1)
8. If (RSS is high) and (Bandwidth is high) and (Jitter is low) and (Battery is low) then (Handover is YES) (1)

Reducing Ping-pong Effect

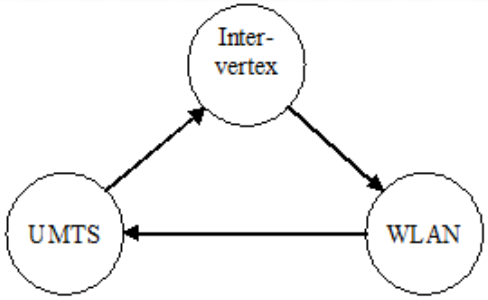
- A user wants to be seamlessly mobile between all available networks.
- During his movement, he will have to perform a large number of vertical handovers.
- Due to sensitive timing of handover execution, the ping pong effect may lead to unsuccessful handovers, destroying the purpose of seamless connectivity.

Reducing Ping-pong Effect (2)

- A new history-based communication graph scheme is presented to perform vertical handover. The proposed scheme has shown a greater number of successful handovers thus reducing the ping pong effect in heterogeneous networks.
- This paper describes an improvement of proposed algorithm. An improvement is based on finding bridges in a graph.

Reducing Ping-pong Effect (3)

- The nodes of the graph are the coordinates at which the vertical handover was successfully executed.
- Edges in the graph are formed when handover is successfully executed. The percentage of successful handovers at certain point defines the weight of an edge from present node to the other heterogeneous node.



Reducing Ping-pong Effect (4)

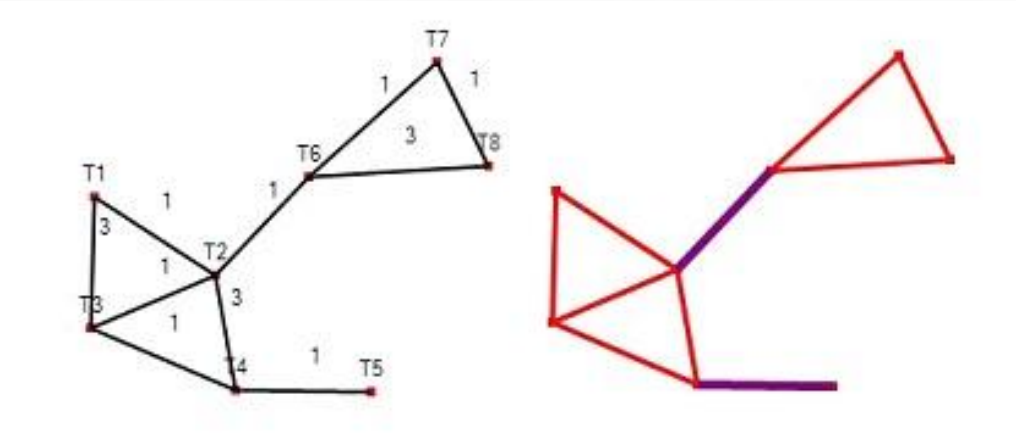
- It's obvious that a graph will have cycles (or loops) between vertices where a ping-pong effect is often expressed.
- If handover is to be performed between two vertices in a graph which are connected with a bridge edge and the weight of a bridge is over 0.8 (percentage of successful handovers through history was over 80%), then the handover occurs immediately.
- Otherwise, it is necessary to perform fuzzy algorithm described in the previous chapter.

Reducing Ping-pong Effect (5)

- It is necessary that only subgraph of a main graph be taken into consideration during the process because it is likely that a huge main graph has a cycle that is not visible at first.
- So, subgraph needs to include vertices between whose handover is initiated, their neighbours and neighbours of their neighbours.
- It is trivial to prove the fact that model on subgraph is mathematically correct if we look at the definition of a bridge in a graph.

Reducing Ping-pong Effect (6)

- An example of finding bridges is given in Figure.
- Bridges are marked in purple. Weights given on edges of a left graph in Figure are not relevant when decision whether the edge is a bridge is made.



Conclusions

- Proposed algorithm is tested for situation when handover is made from LTE to WLAN.
- Since WLAN networks have significantly less coverage, there must be accurate decisions about vertical handover when the user is exiting the coverage of the WLAN network.
- Because of the already mentioned characteristics of fuzzy system, the process of its construction could be modelled in a very similar manner as in the described procedure.

Conclusions (2)

- A proposed model for reducing ping-pong effect presents a new direction that could be used for better performance when vertical handover is done. Graph theory has, once again, proved very useful for solving engineering problems.
- In this paper it is not considered the possibility of vertical handover when one of the network WiMAX network. However, its inclusion in the algorithm would only represent upgrade of a model, i.e. it is not needed to write it from scratch.