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Maximizing the reliability of dual homed, critical services in wireless/cellular networks

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ABSTRACT

In the modern society the wireless access to any service has become a commodity. However, various services have different dependability requirements. For critical services the reliability, i.e., the probability for an uninterrupted service, is utmost important. In wireless/cellular networks the execution of handover is one of the key mechanisms to provide an uninterrupted service for a mobile user. Dual homing may be utilized to increase the service reliability where disjointed access points are used for the two connections across possible different access technologies and network operators. The novelty of this paper is how a shortest path algorithm is used to efficiently find the (near-) optimal selection of access points along a projected route for a dual homed critical service. This optimization for reliability takes the radio connections, including handovers, and backhaul network into account. Backhaul network may be composed of a web of autonomous sub-networks made up of different technologies and layers, for instance SDH over an optical network layer.

1. Introduction

With the evolution of the networks, and the capabilities of user equipment, the access to any services through wireless means is nowadays taken for granted. A myriad of services cover a wide range of needs like e.g. infotainment, machine-to-machine communications, business and health care. Network operators provide wireless coverage with different wireless technologies such as wireless local area network (WLAN), universal mobile telecommunications system (UMTS) and long term evolution (LTE).

Different services have different dependability requirements. For critical services, like emergency handling and control, health care, surveillance and monitoring, the reliability is of utmost importance. For critical services there is a need, at run-time to, identify the access points and handovers along a projected route to allow the user to predict the service reliability. How the projected route is derived is not part of this paper, but may be given by means of navigation tools or physical constraints.

This paper presents how a shortest path algorithm may be used to efficiently find the selection of access points along a projected route for a dual homed critical service that optimizes the service reliability. The obtained optimal selection of access points may be used by handover algorithms and multihoming protocols. This reliability optimization takes the radio connections, handovers and backhaul network into account. The presented approach is a general method applicable for wireless/cellular access where the backhaul network may be composed of a web of autonomous sub-networks made up of different technologies and layers, e.g. SDH over an optical network layer. In principle the approach may be used for Line of Sight optic

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access between the user equipment and the access point [1], but we have focused on wireless/cellular access considered to be most appropriate technology initially.

The probability that the critical service may be completed without any interrupt is given by the metric for service reliability $R(t_m) = Pr\{T_{FF} > t_m\}$ where T_{FF} is time to first failure and t_m is the mission time. Fig. 1 depicts an example network with three network operators, named A, B and C. The access points A1, B1 and C1 are connected to the access controllers, for instance radio network controller (RNC) for UMTS, AC3, BC1 and CC8 respectively over a backhaul network. To ensure uninterrupted service in such an environment access point selection and handover execution are essential mechanisms for a user on the move.

A survey of handover decision algorithms is presented in [2]. To improve the handover performance several proposals exist such as pre-authentication [3,4] and activation of resources in the target network [5]. Common for the proposals described in [3–5] is the usage of Media Independent Handover (MIH) [6] as a framework for obtaining information of access points in the area. Typical handover algorithms are local hop-by-hop based decisions, where handover decisions are taken independently of potential future handovers. The contribution in this paper is a global route handover decision schema combined with an extension of the MIH framework that maximizes the service reliability. A global route handover decision schema takes all necessary handovers along a projected route into account.

To increase the reliability dual homing may be used, where the user equipment has radio connection with two disjointed access points. Examples of multihoming protocols are stream control transmission protocol (SCTP) [7], Mobile SCTP [8], Mobile IPv6 (MIPv6) [9] and Site multihoming by IPv6 Intermediation (SHIM6) [10]. Similar as for handover mechanisms, one of the main challenges with multihoming protocols is the path management, i.e., which access points to use. We define a trajectory as a series of access points used for each of the two radio connections for a dual homed critical service along a projected route.

Even though dual homing is used for the radio connection, it is not given that all used resources in the backhaul network are disjoint and statistically independent. In fact, the opposite is quite common due to co-operation through (cost saving) business relations between network operators. The co-operation has evolved from site sharing and hiring leased transmission into equipment and network sharing [11,12]. Regard Fig. 1 where the backhaul network or parts of it is indicated as possibly shared among the operators. The Media Independent Information Services database (MIIS db), part of the MIH framework, is used for storing and retrieval of dependability information of access points and backhaul network topology.

We show how shortest path algorithms, such as Dijkstra [13] or Bellman-Ford [14], may be used for finding the (near-)optimal trajectory for a dual homed critical service. We will show that the trajectory found is identical to the trajectory found by an ILP optimization. Several techniques exist to improve the performance of Dijkstra algorithm, see e.g. [15–18]. Even though improvements may be shown for some data sets, typical for road networks and time table information systems, they cannot be proved to be asymptotical faster than the original Dijkstra for all data sets.

The rest of the paper is organized as follows. The dependability model of a mobile user is presented in Section 2. This model is used by the shortest path algorithm as described in Section 3 for optimizing the reliability of a trajectory for a dual homed critical service. Optimization of trajectory is performed for a number of network instances and results are presented in Section 4. We conclude this paper in Section 5.

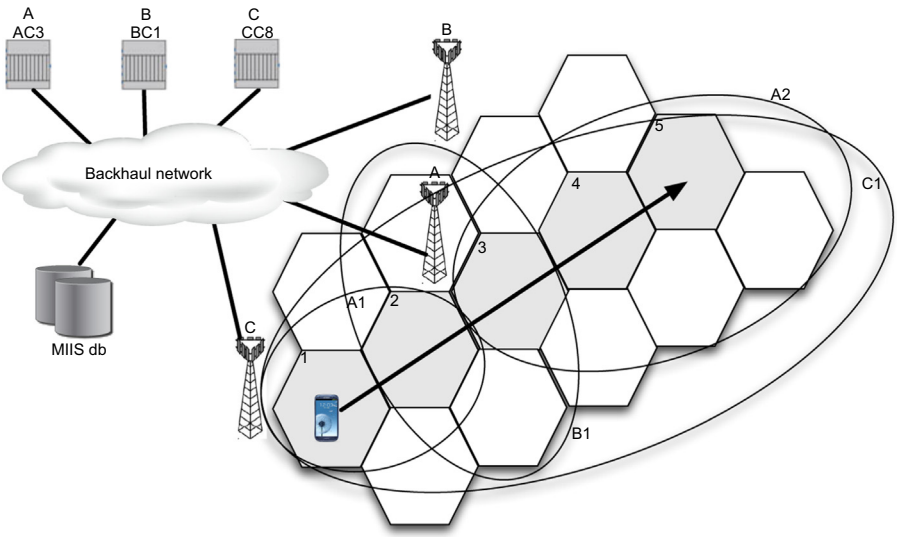

Fig. 1. An example network showing the projected route for a user (the arrow) that crosses a number of virtual cells (hexagons). The access points are controlled by the access controllers AC3, BC1 and CC8 operated by the network operators A, B and C. The MIIS db is used for storing and retrieval of dependability information of access points and network topology.