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Supporting location/identity separation in mobility-enhanced satellite networks by virtual attachment point ☆

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ABSTRACT

Location/identity separation can be used to enhance mobility in satellite networks. However, given the high mobility of non-geostationary satellite networks, usage of conventional binding update schemes will inevitably result in a large number of binding updates. In this work, a novel virtual attachment point based indirect binding scheme is proposed to address this issue. Moreover, a multi-layer service area based vertical update scheme is further investigated to eliminate the ping-pong effect. A random walk model based analysis and a Monte carlo method based simulation are conducted to evaluate our schemes. And the evaluation results demonstrate the validity and efficiency of our schemes comparing to conventional scheme, i.e. mobile IP.

1. Introduction

Mobile network has transformed our daily life. In particular, the growth of mobile network has strongly accelerated the development of the pervasive and mobile computing. However, as more people connect to the mobile Internet, mobile data traffic continues to grow at unprecedented exponential rate today [1]. In order to address the continuously growing mobile traffic challenge, the satellite network is fully explored to satisfy the capacity demand for mobile access, anytime and anywhere [2,3].

However, the traditional satellite communication system [4,5] continues to operate as it did when dominated by fixed ground stations, neglecting the support for high mobility endpoints like aircrafts, high-speed trains, etc. The lack of support for mobility means that mobile endpoints have to find a fixed ground station to forward their traffic, which is an unacceptable restriction [6]. Moreover, most research [7] on satellite networks only takes the movement of satellites into account, simply ignoring the movement of endpoints, because of the huge discrepancy in velocity between the satellites and the endpoints, which is not accurate. Consequently, enhancing mobility is a significant consideration in designing future satellite networks [8].

Traditionally, geostationary satellites have been preferred for communication due to the reason that as little as three such satellites, each separated by 120 degrees of longitude, can cover the entire planet [9]. Nevertheless, the advantage of the non-geostationary system is that the satellites' nearness to the ground enables them to transmit signals with much smaller delay. In addition, since the signals to and from the satellites need to travel a relatively short distance, non-geostationary systems can also operate with much smaller user equipment (e.g., mobile portable devices) than systems using a higher orbit [10].

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However, these advantages come with a price: lower orbit satellites move with higher speed relative to the earth's surface, resulting in high dynamic in the satellite network topology [11].

In some emerging terrestrial mobile network architectures, it is commonly accepted wisdom that a cleaner separation of identity and location is instrumental to enhancing mobility [12]. However, in terrestrial mobile networks, only endpoints are subject to motion while network attachment points remain fix. Whereas, in non-geostationary satellite networks, both mobile endpoints and satellites (i.e., actual network attachment points) keep on moving which makes them experience frequent handovers [7]. Therefore, different from terrestrial network, a main issue is that relative movement between a mobile endpoint and a satellite makes the access device's network address corresponding to its current satellite network attachment point becoming elusive. Location/identity separation solution requires an endpoint to send binding update request every time it changes its network attachment points [13]. Given the high frequency of handovers, this approach will result in a large number of binding update requests and consequently affect the scalability.

To address this issue, a key design decision in this work that helps achieve the goal of enhanced mobility is a logical separation of the movement of satellites and the movement of endpoints, which is enabled by a novel virtual attachment point based indirect binding scheme. In our scheme, a virtual overlay network consisting of fixed virtual attachment points is superimposed over the physical topology in order to hide the mobility of satellites from the terrestrial endpoints. A virtual attachment point regularly embodied by different satellites indicates a constant network location (decided from its location in the fixed virtual overlay network topology). Then a binding between the identity and the fixed virtual attachment point rather than the dynamical physical satellite flying overhead is carefully maintained by a identity-to-location resolution system. The basic idea of our scheme is to make binding update independent of the motion of satellite and only associated to the endpoint's virtual attachment point. Thus, our scheme mitigates the effect of frequent satellite handover on the binding update rate.

In addition, a novel multi-layer service area based vertical update scheme is proposed that can be used for overcoming ping-pong effect and further decreasing the binding update rate. A key insight underlying this scheme is tactfully arrange the layout of multi-layer service area so that the endpoint is placed at the center area of the new service area after a binding update process, which achieves binding updating hysteresis and then reduces binding update frequency due to ping-pong effect. The proposed schemes are analyzed based on the random walk model. Moreover, to clarify potential advantages of our schemes over traditional schemes, a contrast simulation between mobile IP scheme and our two schemes in term of binding update rate is presented to demonstrate the effectiveness of our schemes.

The remainder of this paper is organized as follows. Section 2 introduces mobility management issues. Section 3 presents the virtual attachment point based indirect binding scheme. Section 4 presents the multi-layer service area based vertical update scheme. Section 5 details a random walk model based model for our two schemes. Besides the analytical results obtained by solving the model, Section 5 also presents the contrast simulation to evaluate the performance of our schemes and discusses the obtained simulated results. Finally, the paper is concluded in Section 6.

2. Mobility management issues

In this section, we classify the approaches to handle mobility in terrestrial mobile networks, and then we give an overview of the mobility management in location/identity separation approach.

2.1. Handling mobility in terrestrial mobile networks

Mobility in terrestrial mobile networks has been extensively studied for a long time in conjunction with protocols such as mobile IP, LISP and HIP. Based on how they go from the identity of an endpoint to the endpoint itself, we find that they explicitly or implicitly embed one of two approaches to handling mobility: agent-based forwarding schemes and identity-to-location resolution schemes.

Agent-based forwarding schemes, e.g., Mobile IP [14], i3 [15], are simple, as an endpoint remains oblivious to the mobility of other endpoints. This scheme routes packets to a home location, and the home agent tunnels all data packets to the endpoints current location. No identity-to-location resolution is needed at connection initiation time as an identity maps to a home agent address (e.g. an IP address in Mobile IP) that rarely changes. This scheme enables seamless mobility of one or both endpoints at any time and is oblivious to fixed endpoints, but consequently have to route all packets through the home agent potentially causing significant routing stretch [16,17].

On the other hand, identity-to-location resolution schemes, also known as location/identity separation approaches, e.g., LISP [18], HIP [19], rely on a logically centralized mapping system to resolve identities to locations at connection initiation time and in order to handle mobility, but does not suffer from data path inflation. In some emerging terrestrial mobile networks architectures (e.g. MobilityFirst [20]), it is commonly accepted wisdom that these approaches are more promising solutions of frequent mobility.