BIGAP – A Seamless Handover Scheme for High Performance Enterprise IEEE 802.11 Networks

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***Abstract*—We demonstrate BIGAP, a novel architecture providing both high network performance as well as seamless handover in Enterprise IEEE 802.11 networks. The former is achieved by assigning different channels to co-located APs to fully utilize the available radio spectrum. The latter is achieved by providing a mechanism for below MAC-layer handover through exploiting the Dynamic Frequency Selection (DFS) capability in IEEE 802.11. In essence BigAP forces clients to change AP whilst they 'believe' they are simply changing channel. BIGAP is fully compatible with 802.11 and requires no modifications to the wireless clients.**

I. Introduction

Nowadays enterprise IEEE 802.11 wireless networks (WiFi) have to support truly mobile users (smartphone/tablet) and hence require much better mobility support indoors and outdoors. However, just providing coverage is not sufficient anymore as capacity hungry novel applications like multimedia streaming applications, mobile HD video, social networking & cloud storage need to be supported.

Enterprise IT departments tackle this issue by a very dense deployment of Access Points (AP) to allow each client Station (STA) to connect with a very close AP. To avoid co-channel interference and competition between co-located APs, neighboring APs are operated on different RF channels. This is a promising approach as with the new 802.11ac standard the available spectrum in the 5 GHz further increases and is sufficient to allow channel reuse and segmentation of APs into separate collision domains even in dense AP deployments [1].

Although, mobile STAs in a dense WiFi network can choose from many possible APs, this degree of freedom is not fully exploited in 802.11 resulting in restricted mobility. This is because in standard 802.11 STAs select the APs they would like to associate using pure local information, e.g. signal strength. This is suboptimal as it leads to load imbalance. Moreover, normally once associated STAs stay connected to the AP even if there is an AP which is able to provide better service quality, e.g. higher link quality or lower utilization [2].

Therefore, an infrastructure-initiated handover scheme which allows seamless mobility and client load balancing is of fundamental importance in Enterprise WiFi networks. We demonstrate BIGAP, an architecture for enterprise WiFi networks, which is efficient, i.e. scales with the number of serving STAs and AP density, while providing support for seamless handover for mobility management and load balancing. It does not require any hardware/driver changes on the client and AP side and is therefore fully compatible with commodity 802.11n/ac cards which support Dynamic Frequency Selection. BIGAP decides on the channel assignment to APs on a long-term basis whereas the decision by which AP a particular STA is served is based on short-term information like channel-state information (mobility) and traffic conditions (load balancing).

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II. BIGAP's Design Principles

Currently the only applicable approach for infrastructure-initiated handover which does not require modifications on the client devices is the DenseAP hard-handover scheme [3]. DenseAP's hard handover scheme removes the STA stickiness by transferring the handover decision from the client to the infrastructure, but leaves the outage duration caused by the amount of time the STA needs for the connection build-up with the new AP. This duration includes the delays caused by scanning/probing, authentication and re-association. BIGAP decreases the network outage duration and removes all aforementioned delays by transferring the current state of the STA from the serving AP to the target AP. To enable this possibility, the BIGAP topology uses a single global BSSID for the whole ESS and thereby for all APs. From the STAs point of view, the whole ESS including all APs seems like one BSS or one big AP. As the same BSSID operated on the same RF channel would cause collisions, duplicated frames in the backbone and would lead to a high channel utilization, BIGAP uses different RF channels for all co-located APs. For performing the handover process, BIGAP exploits the 802.11 DFS functionality and leads the STA to believe that the serving AP will perform a RF channel switch. In actual fact, the serving AP remains on its current RF channel but the target AP is operating on the new RF channel. Due to the fact that all APs use the same BSSID and due to the fact that the current state of the STA on the old AP was transferred to the new AP, the STA believes the new AP is the old AP which has also switched the RF channel. By relying on these principles the communication can be continued without any further outage except the time needed for channel switching in client device.

BIGAP does not require any modifications to the STAs but requires the support of 802.11n/ac which includes the IEEE 802.11h amendment. Further, BIGAP requires the existence of a sufficient large number of available RF channels so that different channels can be assigned to co-located APs. This is feasible because there are enough channels available in the 5GHz band, i.e. 9 and 25 (with DFS) channels respectively.

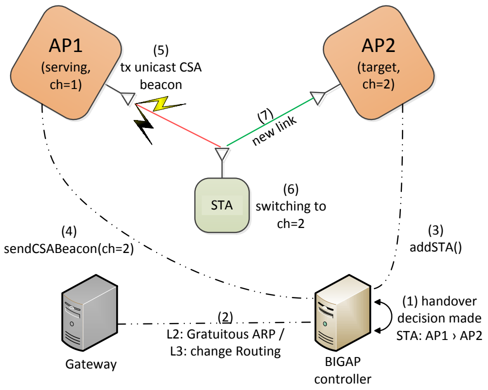

Fig. 1. Client STA is handed over from AP1 to AP2.

BIGAP exploits the possibility of DFS to announce channel switches to trigger a channel switch within STAs and further to perform the handover operation. To achieve this, the BIGAP controller instructs the serving AP to send a unicast beacon frame containing a Channel Switch Announcement Information Element (CSA-IE) with the RF channel of the target AP. Receiving this CSA-IE triggers the channel switching in the STA to the desired RF channel. The selected channel determines implicitly the target AP since there is at most one AP using the same channel in a BIGAP collision domain.

For more details on the BIGAP approach and its implementation as well as experimental and analytical evaluation results, please refer to our full paper [4].

III. BIGAP - STA Handover

In case a STA is not associated with a proper AP, i.e. due to load balancing, interference and mobility issues, a handover operation is performed by the BIGAP controller. As an illustrative example Fig. 1 shows the required steps to perform a handover of *STA* from *AP1* to *AP2*:

1) A decision was made in the BIGAP controller to handover *STA* from *AP1* to *AP2*.
2) The traffic flows towards *STA* need to be routed over *AP2*.
3) The BIGAP controller associates and authenticates *STA* on the target AP, *AP2*, using the information about *STA* provided by *AP1*. This make sure that after the handover operation the *STA* is properly registered within *AP2* since otherwise *AP2* would respond with an disassociation frame and will not accept data frames.

4-5) BIGAP controller instructs *AP1* to send out a unicast beacon containing a CSA-IE with the channel set to the target AP, here 2, destined to *STA*.

6) On successfully receiving the unicast beacon containing the CSA-IE the corresponding *STA* performs channel switching as specified in the IEEE 802.11 standard.
7) Since both *AP1* and *AP2* have the same BSSID, aka MAC address, the *STA* does not notice that it is being served after the channel switch by another AP, *AP2*. *STA* continues with its communication.

Fig. 2. Demo setup, enables direct comparison between BIGAP soft-handover and standard hard-handover scheme.

IV. Demo Setup

The objective of the demo is to show that BIGAP supports seamless handover and therefore provides a solution that preserves a good user experience in mobility and load-balancing scenarios. Fig. 2 shows the demonstration setup with the components involved; i) BIGAP controller in the middle, ii) two APs (Intel NUC with Atheros 802.11n chipsets) and iii) two client STAs (unmodified Android commercial off-the-shelf smart-phone and tablet). BIGAP was configured to perform periodic handover operations: every 30 s a client is handed over from one AP to the other. One of the clients is handed over using the proposed BIGAP soft handover scheme whereas the other is handed over by the standard hard handover. For each client STA two traffic flows are set-up. First an ICMP ping showing the round-trip time (RTT) from the controller to the client. And second, an unbuffered UDP video stream sent from the controller to the STA.

The audience can experience the advantage of the proposed BIGAP handover scheme. Specifically, it can be observed that during the BIGAP soft handover operation the quality of the video stream is not negatively affected, i.e. judder-free motion without artifacts. In parallel as a direct comparison the standard hard handover shows significant juddering and artifacts. This observation can be confirmed by the plot illustrating the RTT and packet loss of the ICMP flows. With the BIGAP soft handover, the RTT is only slightly affected with just occasional packet losses. In contrast, the hard handover scheme causes bursts of packet losses with durations of several seconds.

References

[1] S. Biswas, J. Bicket, E. Wong, R. Musaloiu-E, A. Bhartia, and D. Aguayo, "Large-scale measurements of wireless network behavior," in *Proceedings of the 2015 ACM Conference on Special Interest Group on Data Communication*. ACM, 2015, pp. 153–165.

[2] V. Sarawat, B. McKibben, and N. Allanki, "Wireless access point load balancing," Dec. 13 2014, uS Patent App. 14/569,669.

[3] R. Murty, J. Padhye, R. Chandra, A. Wolman, and B. Zill, "Designing high performance enterprise wi-fi networks." in *NSDI*, vol. 8, 2008.

[4] A. Zubow, S. Zehl, and A. Wolisz, "BIG AP – Seamless Handover in High Performance Enterprise IEEE 802.11 Networks," in *Network Operations and Management Symposium (NOMS), 2016 IEEE*, April 2016, accepted for publication.