Service Outsourcing and Billing in Inter-domain IMS Scenarios

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***Abstract*— Resource sharing in commercial mobile networks may present operators with options to cut costs and prevent network churn. In resource sharing, when the network experiences resource constraints, the operator can negotiate with other reachable networks to outsource the provision of network access serveices. The revenue earned from user payments will be shared by the home operator and the serving operator. Operators participating in service outsourcing are faced with financial challenges with regard to network revenue sharing. Moreover, an operator's users are placed under service control of the visited operator, a situation that may impact customer experience. On the other hand, the visited operator allocates network resources to visiting users, thus there is a risk of service blockage for home users. In this paper we explore resource sharing in inter-domain frameworks, and investigate factors that influence revenue distribution amongst involved operators. We develop strategies for use by operators to maximize revenue from resource sharing. This work is done in the domain of IP Multimedia Subsystem communications.**

***Index Terms*— Charging, IP-CAN, QoS, Service outsourcing**

I. Introduction

Resource sharing in commercial mobile communications (or network access service outsourcing) differs from conventional roaming [1] in terms of revenue apportioning amongst involved operators [2]. Technologically, there is a difference with regard to the outsourcing triggers and transactions. In outsourcing, the home operator explicitly initiates a roaming transaction targeting a specific visited operator's access network. Thus, a reference point is required between the home operator and the visited operator. An important aspect of service outsourcing, as opposed to conventional roaming is the imposition of the same service charge to the user regardless of using the home network or the visited network. Service outsourcing becomes necessary when a given operator experiences resource constraints on an access network on which a user is attached. The network will block service requests made by the user requiring unavailable network resources. Frequent service request or call blocking may lead to user dissatisfaction and eventual network churning. Service outsourcing will enable the home operator to handover unserviceable requests for network resources to federated operators. Thus, the user will access home network services using a visited operator access network.

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As 3G networks evolve towards the Long Term Evolution (LTE) [3], there will be great abundance of resources; however, periods of resource constraints will still arise. The dominant business scenario will involve operators bundling services in subscription packages. The bundles will be composed of network transport services, and services and applications offered on top of the transport network. Charging for the bundled services will be achieved using converged charging systems. Converged charging and billing systems are favorable to users due to their simplicity. Predictability of service charges is also an important aspect of a charging system for users. Thus, in roaming scenarios subscribers may not understand the reason for incurring higher charges for access to the bundled service.

In scenarios with multiple potential visited operators, the home operator may select a serving network for outsourced user sessions based on predefined parameters and algorithms. Moreover, the potential visited operators may bid to offer services to the outsourced sessions in response to the outsource request. The home and visited operators will benefit from shared revenue accruing from user payments. However, they are also faced with critical challenges affecting the normal flow of revenue in scenarios where service outsourcing is not enforced. The home operator would lose potential income if resources became available on his access networks, while some user sessions remain actively connected via a visited operator's network. On the other hand, a visited operator who admits outsourced sessions may end up blocking sessions belonging to home subscribers if they request services while network resources are allocated to outsourced sessions.

To ensure the financial benefits of service outsourcing outweigh the potential losses, appropriate values for critical outsourcing parameters may be used to influence the proportion of apportioned income for a given operator. This creates a game theory scenario with a set of rules, strategies and payoffs. The game depends on a set of outsource parameters, i.e., the offer price, the outsource duration, and the required QoS level. The offer price is the monetary amount the home (or custodian) operator intends to pay to the visited (or candidate) operator to offer the outsourced service; the outsource duration is the initial period over which the session would remain

outsourced to the candidate network; and the required QoS level is defined by a QoS class and up-link and down-link bandwidth values [4].

By negotiating appropriate values of the outsource parameters, either operator may maximize on the benefits of service outsourcing. In this paper we present and analyze parametrization aspects to be considered in making service outsourcing decisions. We also present design considerations for service outsourcing based on IMS transactions. Service outsourcing using IMS communications requires an IMS charging platform. Hence, we present a testbed implementation of service outsourcing and IMS charging. Analytical results of service outsourcing are presented; these are complemented by proof of concept IMS charging results. The rest of this paper is structured as follows: in section II we briefly review the aspects related to inter-domain network access service outsourcing; in section III we formulate solutions for the aforementioned challenges, we also present design considerations for the deployment of service outsourcing mechanisms in a Next Generation Network scenario based on the IMS; in section IV we explore implementation considerations for service outsourcing; in section V we present testbed results and discussions; section VI concludes the paper.

II. Service Outsourcing Aspects

The IP Multimedia Subsystem (IMS) is a service convergence framework that provides a cost-effective and network controlled platform for the design and delivery of IP-based communications and media services [5]. It defines a horizontally layered structure that utilizes existing communication networks and protocols. The structure is composed of an application (service) plane, a control (signaling) plane and a transport (media) plane. The application plane hosts different application servers e.g., presence, IPTV, conferencing etc. The main components of the control plane are the call session control functions (CSCF), which perform registration of users and the establishment and control of IMS sessions. There is a home subscriber server (HSS) to store user and network related information, e.g., user profiles. Other entities belonging to the control plane include gateways that perform the translation of signaling information between different network architectures. The transport plane contains network nodes that lie in the path of media traffic between the communicating equipment, e.g., two or more user equipment (UE), or a UE and an application server. QoS policy and charging control should be done at each plane of the IMS in order to enforce resource usage control and charging [6]. The type of QoS and charging information generated at each plane depends on the communication scenario being used, e.g., when a user is connecting via the home or visited network.

When users connect to the IMS via the home network their sessions are controlled by QoS policies defined by the home operator only. Charging information is generated and processed by the home operator. Roaming across networks belonging to other operators enables users to access network services in areas where, or during periods when, the home operator does not provide network access. Access to network services[1] via the visited network is achieved while utilizing subscription information stored in the infrastructure of the home operator. In conventional roaming it is at the discretion of the user to initiate service access via a given visited network, and for that reason QoS and charging policies applicable to the roaming user are not negotiated between the home and visited operators. However, roaming agreements exist between the home and visited operators to facilitate the exchange of subscriber information for authentication, authorization and accounting [1]. Accounting is done for service usage for the sake of charging and billing.

Inter-domain service outsourcing differs from roaming in terms of the proportion of network revenue that is apportioned to the custodian and candidate operators, and also in the amount of service charge that is levied to the user. Moreover, the custodian operator selects the candidate network and negotiates service delivery terms for the user. There are many similarities and challenges facing service outsourcing and roaming. Fundamental challenges facing roaming in 3G and future IP networks are explored by A. Roos et. al [1]. Roaming enables service delivery to subscribers via a visited operator's network; in terms of financial implications the subscriber meets the cost of service delivery for the full path between the Home Operator (HO) network and the visited operator (VO) network[2]. Subscribers experience higher charges whenever they roam to a VO network. In scenarios with two or more VO networks, to which users could attach, users may choose a preferred network.

Service outsourcing requires a functional QoS and charging platform. In the IMS QoS and Charging mechanisms have been standardized by various standards bodies. Charging specifications for the IMS are contained in 3GPP TS 32.260 [7] and 3GPP 23.203 [8]. Both online and offline charging are standardized. Online charging utilizes the Diameter credit control application; credit re-authorization is required upon the expiry of an *interim* period. The frequency of the *interim* messages exchanged across the Ro interface, between the Charging Trigger Function (CTF) and the Online Charging System (OCS) adds to the system overhead caused by charging. In offline charging, the CTF starts charging processes upon the detection of a chargeable event. Accounting *start*, *interim* and *stop* messages are exchanged across the Rf interface between the CTF and a Charging Data Function (CDF) [6]. In offline charging credit usage supervision is not performed. The use of Diameter Attribute Value Pairs (AVP) [9] allows the exchange of any kind of information between the CTF and the online and offline charging systems. Interaction between charging systems of the home and visited operator is required for service outsourcing. For this project, the 3GPP standardized S9 reference point is considered [10].

In our previous work [2] we introduced and explored the basics of service outsourcing in Inter-domain frameworks. In this paper we explore optimization mechanisms to enable the custodian and candidate operators to maximize on the benefits

[1]In this document services refer to IMS services

[2]This case accounts for only a sub-set of the charges, which would be higher when the leg between the HO network and the user (node) at the other end of the communication is considered.

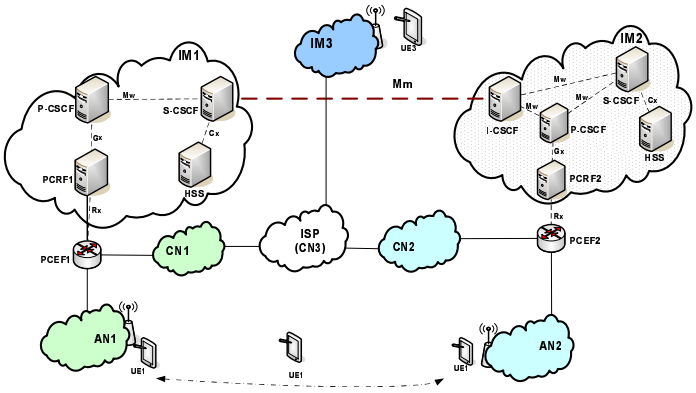

Fig. 1. Service Outsourcing Scenario

of service outsourcing.

III. Optimal considerations for service outsourcing

The following scenario is considered in modeling a scenario for the work reported in this paper. The home operator is the operator with whom a user has an active subscription. The HO (or custodian operator) aims to provide ubiquitous service delivery to subscribers while maintaining the same level of charge for service usage. Limited capacity in access networks and the absence of radio coverage are some of the reasons that result in failed service delivery in mobile communication networks. Instead of blocking unserviceable sessions, the HO negotiates with a VO (also referred to as a candidate operator) to offer network access services to users of these sessions at a fee.

The service delivery framework allows a HO of a network experiencing capacity constraints to request usage of a candidate operator's network to provide IMS services to subscribers. QoS and charging policy negotiations between the HO and the candidate operator include the required QoS in terms of session parameters, the required or available access network type, service outsourcing offer price, per-unit charges for service delivery on the candidate operator network, duration of time the session would remain outsourced to the candidate operator's network and intervals for reporting session progress to the HO network. A general view of the service outsourcing scenario is given in Fig. 1. In the scenario the operator of IMS network 1 (IM1) negotiates a service outsourcing transaction with the operator of IM2 to provide services to the user of IMS client UE1. Under conditions with adequate capacity on the HO network UE1 would access IMS services using access network 1 (AN1), and would be blocked during congestion periods. However, after a successful service outsourcing transaction UE1 may access network services via access network 2 (AN2).

In Fig. 1 usage of AN1 and CN1 resources is controlled by IM1, while IM2 controls resource usage in AN2 and CN2. UE1 invites another client UE3 located on IM3 to a media session with specific QoS resource requirements that are negotiated in terms of session parameters. Several factors, e.g., lack of sufficient resources for the IMS session in AN1

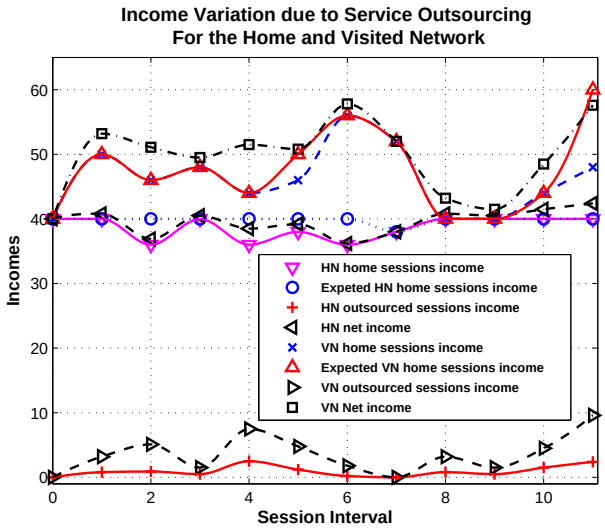

Fig. 2. Operator income patterns due to service outsourcing

would trigger an outsourcing transaction to move the session to AN2. The IMS session invite would proceed via IM2. This scenario assumes that AN1 and AN2 overlap in terms of radio coverage; moreover a method is required to signal UE1 to perform a handover from AN1 to AN2.

The fee paid by the HO to the VO can be set through several means. It can be pre-set to a fixed monetary value for a given set of QoS resources, e.g, a minute of a voice call using a given codec. Alternatively, the operators may negotiate the offer price for every outsource request. A candidate operator may challenge the initial offer price, thus requiring a subsequent offer by the HO.

A. Financial implications of service outsourcing

Service outsourcing enables the HO operator to provide services to subscribers even when the network is congested, thus ensuring customer satisfaction and minimizing the churn rate. Although the custodian operator earns a small income from every outsourced session; the income earned is a small fraction of the amount paid by the user. The candidate operator receives the remainder. This outsource income has an effect on the net income of each operator. If during any outsource duration the demand for resources on the custodian network drops considerably, it would be possible for some outsourced sessions to be served. However, it is expected that operators in an outsourcing agreement will define the outsource duration over which an active outsourced session would be served on the candidate network. Thus, the custodian network may not recall outsourced sessions when an abundance of resources arises; hence substantial income that could be earned by not outsourcing sessions would be lost. This situation is reflected in Fig. 2 when the net income for the custodian operator is less than the expected income if service outsourcing were not done. On the other hand, the candidate operator would lose some marginal income if service requests from home[3]

[3]Home subscribers in this case refers to users who are subscribed to the candidate network

subscribers could not be admitted into the network due to serving outsourced sessions. This would happen when the candidate operator's outsourced sessions income is less than the potential income of blocked sessions.

Since the custodian operator only receives income that is a fraction of what subscribers pay, the outsourcing penalty revolves around the reduced net income for each session. The difference between the net income received by the custodian network and the charges levied to the user for a given session is termed and the Outsourcing Cost Margin (OCM). It is thus the target of the custodian network to minimize this margin. OCM can be eliminated by not outsourcing unserviceable session requests; however, the advantages of outsourcing would not be exploited.

Delaying to outsource an unserviceable request, i.e., outsource holding, can be used to avert the OCM. This requires determination of the holding duration, and other factors, e.g., the maximum number of service requests that may be held before outsourcing becomes inevitable. On the other hand the candidate operator may use mechanisms like increasing the acceptable outsource offer price with every blocked home service request in a given time frame. In a competitive multi-candidate operator scenario setting a high acceptable outsource offer price may result in loss of outsourcing opportunities.

B. Operator strategies in service outsourcing

The custodian operator may use a low offer price to guarantee the retention of a bigger portion of user payments. On the other hand the candidate operator would push the offer price higher, towards the amount home subscribers pay for network transport services.

The final offer price for the outsourced session will be set after both parties agree to a given value. Operators may minimize the OCM through selecting appropriate values of the outsource duration. When service quality differentiation is effective on a given network, some users may opt for lower quality services if their decision would translate into lower tariffs. Thus, operators may outsource sessions belonging to these users to accommodate higher quality sessions that generate more income. This may contribute to lowering the OCM.

A home network would benefit from network access outsourcing by preventing call blocking; on the other hand a visited network would benefit from increased resource utilization efficiency, and additional income from abundant resources. The agreed offer price may be favorable to both operators, to one operator or to neither operator. The outsource duration can be used to influence the ultimate value of revenue earned from the outsourced session. If the outsource offer price favors an operator, the operator may prefer to negotiate a longer outsource duration for the session. On the other hand a shorter outsource duration may be preferred when the offer price is not favorable. An operator's negotiation of a more favorable offer price or outsource duration may be influenced by their optimism with regard to service outsourcing.

An optimistic operator utilizes every opportunity that involves service outsourcing, while a pessimistic operator may ignore such opportunities in anticipation of utilizing available network resources to serve home users. An optimistic custodian operator would outsource any service request that cannot be admitted to the network at request time, while a pessimistic custodian operator may defer outsourcing of unserviceable sessions in an attempt to avoid loss of income if resources became available during active outsource periods. On the other hand, an optimistic candidate operator would admit any outsourced sessions if resources are available; a pessimistic candidate operator may reject these opportunities in anticipation of receiving resource requests from home users.

Thus, it is clear that pessimistic operators prefer to keep the OCM as close to zero as possible. Call blocking is likely to be high on a pessimistic custodian operator's network. Lower efficiency in resource utilization might prevail on a pessimistic candidate operator's network. It is therefore important to formulate mechanisms that would give more confidence to pessimistic operators to utilize outsourcing opportunities when they arise. In order to participate in an outsourcing transaction, a pessimistic operator would try to push the value of the outsourcing offer/accept price in their favor.

A custodian operator may prefer to outsource the lower quality sessions that require lesser resources and are charged at lower tariffs as a way of minimizing the overall OCM. Various design features need to exist in the network for this to be possible. Ultimately, an operator whether custodian or candidate, optimistic or pessimistic will perform a strategic move that may enable them to maximize on the benefits of service outsourcing; overall achievement of higher service related income and network efficiency should be achieved as well.

C. The design of an IMS charging framework for service outsourcing

Service outsourcing based on the IMS requires a charging system built according to IMS specifications on the HO's and VO's networks. The charging system may support both offline and online charging. Essentially the charging system is composed of one or more Charging Trigger Functions located where service usage control is enforced. The CTF performs service usage charging and sends charging data records to the charging data function, for offline charging and the Online Charging System for online charging.

In online charging, upon receiving a request for services a Credit Control Request (CCR) is sent to the OCS, which responds with an allocation of credits to authorize service usage for a given time frame. Fig. 3 illustrates the internal operation of the OCS credit control functions. Service usage is stopped on credit exhaustion, or as requested by the user. In offline charging, the CTF accounts for resource usage and sends *interim* reports to the CDF. Service usage stops only when requested by the user.

For the support of service outsourcing, interactions between the HO and VO charging systems is required. We utilize the 3G S9 reference point for these interactions. This interface is be based on Diameter. We develop service outsourcing request and response methods to transfer the offer prices,

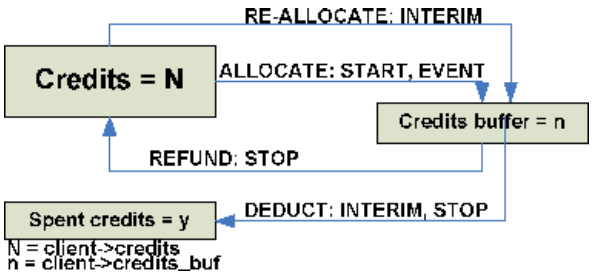

Fig. 3. IMS online charging system

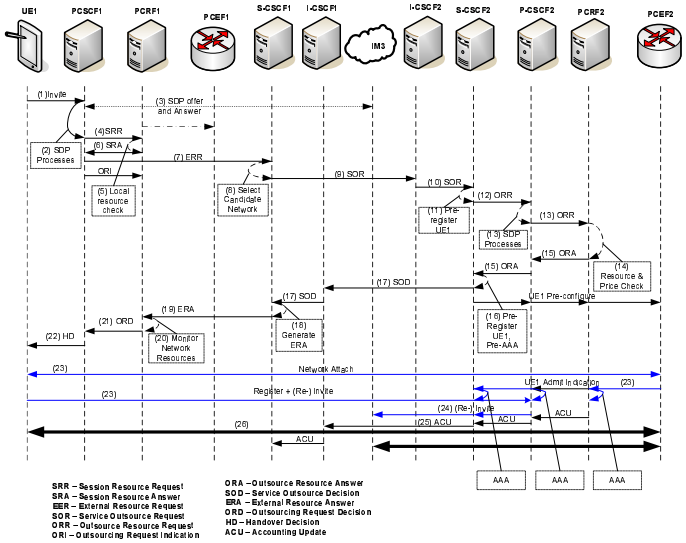

Fig. 4. Service outsourcing signaling messages

outsource duration and session QoS information across the S9 interface. An outsourcing transaction involves the exchange of several SIP and Diameter messages. Fig. 4 depicts the message exchange for a typical outsourcing session. It is clear that when outsourcing involves many sessions the network overhead would be very large. Bundled outsourcing may be used to minimize the signaling overhead. In bundled outsourcing the custodian network determines the need to outsource several sessions in a time frame; instead of performing the process sequentially for each session, it performs outsourcing of all the sessions using the same messages.

IV. Implementation and Testing

This paper utilizes an IMS prototype implemented using the Open Source IMS (OSIMS) software from Fraunhofer Fokus institute [11], and the UCT IMS client [12]. We developed an IMS charging system with an attempt to comply with 3GPP standards; however, we also included optional mechanisms that have not been standardized. We also created necessary Diameter AVPs that are yet to be defined by standardization bodies. The testbed comprises of two IMS domains, with IP-CANs deployed using, fixed Ethernet, WLAN and WiMax. The testbed layout is shown in Fig. 5. The Ro, Rf, Rx, Gx and S9 interfaces are developed and implemented using a C Diameter peer (cdp) package.

Before triggering service outsourcing, the calling UE is attached to the imscore domain. It establishes a VoIP session

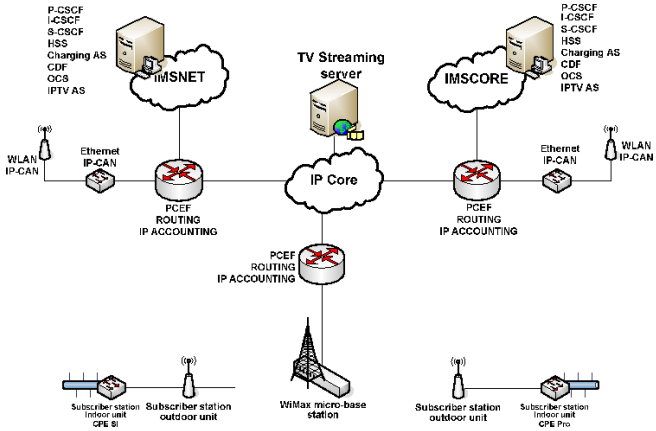

Fig. 5. The IMS testbed layout

with a callee UE attached on the Ethernet switch served by the WiMax subscriber station. The calling UE is then triggered to handover to the imsnet domain. The media session information of the active session is sent to the imsnet domain in an outsourcing request. Upon accepting the request, the imsnet network replies with network attachment information, i.e., the IP address to be used by the calling UE to attach to imsnet IP-CAN. The imscore network aliases the supplied IP address to the UE's current IP address and commands it to associate with the imsnet IP-CAN. After successful association to the new network, the UE refreshes its registration with the imscore domain; note the information now traverses the imsnet IP network. Upon successful re-registration, the UE sends a re-invite message to the callee UE to re-establish the VoIP session.

Charging for the session on the imsnet domain is required at the media plane. Thus, IMS flow level charging is used. The incurred charges are offset by payments received from the HO (imscore). When using online charging mechanisms, Diameter credit control is used in the HO's network to allocate credits to the VO for the session. The functionality of the credit control mechanism for online charging was assessed. The system was used to exchange inter-domain credits for outsourcing transactions set to different outsource lifetimes. The results of the system are given in the next section.

V. Results and Discussions

Numerical analysis results of the expected financial distributions for the HO and VO were given in Fig. 2. It can be seen that both operators benefit from service outsourcing. However, it was pointed out that the possibility of financial loss exists for both operators. Hence it is necessary for each operator to apply strategies to achieve maximization on the outsourcing benefits.

The service outsourcing framework was subjected to proof of concept tests. Using online charging mechanisms, after receiving a Diameter Credit Control Answer (CCA) from the HO's OCS with appropriate credit allocations defined in the outsourcing transaction negotiations (i.e., a once-off charge of 10 credits and a time-based charge of 1 credit per second) the VO network started offering services to

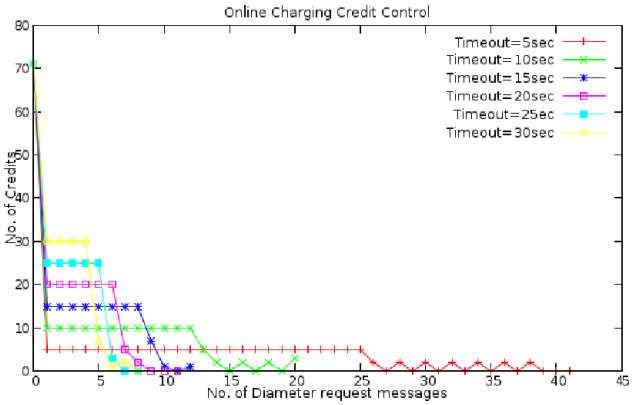

Fig. 6. Diameter Credit Control trends at the HO's OCS

the users. The outsource durations were varied for different sessions; this implicitly defined the *Interim* report periods for the charging system. The outsourcing duration periods ranged from 5 seconds and 30 seconds. The OCS was configured to replenish the exact amount of consumed credits as contained in the reports. For initial tests, we used a scenario where the outsourcing period is automatically renewed and remains active until user credit exhaustion, or session termination. With an initial balance of 200 credits and the outsource duration set to 30 seconds, service termination due to credit exhaustion occurred 8 seconds after the 5th *interim* report (outsource refreshing) was sent to the HO. This is shown in the graph in Fig. 6, which also shows the number of Diameter outsourcing messages sent to the HO for different outsource lifetimes.

VI. Conclusions

This paper has explored the concept of network access service outsourcing in inter-domain scenarios based on the IMS. This concept involves commercial network resource sharing amongst competing mobile network operators. It has been shown that every operator who participates in service outsourcing can benefit financially. The home operator would benefit by serving service requests from subscribers during times when the home network lacks the capacity to service the requests. This achieves the goal of minimization of network churn probability. On the other hand the visited operator benefits from utilization of intermittent excess network capacity; thus network efficiency and incomes are boosted. Some potential financial implications for both operators exist with regard to service outsourcing. Possible solutions to these challenges have been discussed. An implementation of an IMS charging framework, and service outsourcing was done. Proof of concept tests were performed on the testbed, and results have been presented and discussed.

The project work addressed in this paper is open to further extension involving real mobile operators, to determine the feasibility of service outsourcing.

References

[1] Roos M. Hartman and S. Dutnall, "Critical Issues for Roaming in 3G," *IEEE Wireless Communications*, vol. 10, pp. 29–35, Feb 2003.

[2] Vitalis G. Ozianyi, Vitor Jesus, Susana Sargento, Rui Aguiar, Neco Ventura, "Virtual Capacity Expansion Through Service Outsourcing," *IEEE WCNC*, Mar-April 2008.

[3] Ekstrom H, Furuskar A, Karlsson J, Meyer M, Parkvall S, Torsner J, Wahlqvist M, "Technical solutions for the 3g long-term evolution," *IEEE Comm Mag.*, vol. 44, pp. 38–45, Mar. 2006.

[4] 3GPP, "Technical Specifications Group Services and System Aspects: Quality of Service (QoS) concept and architecture - rel. 8," *3GPP TS 23.107*, Dec. 2008.

[5] Miikka Poikselka, *The IMS - IP Multimedia Concepts and Services in the Mobile Domain*. John Wiley and Sons Ltd., 2004.

[6] R. Kuhrie et. al, "Charging in the IP Multimedia Subsystem: A Tutorial," *IEEE Communications MAgazine*, vol. 45, pp. 92–99, July 2007.

[7] Gonzalo Carmarillo and Miguel Garcia, *The 3G IP Multimedia Subsystem (IMS) - merging the Internet and cellular worlds*. John Wiley and sons Ltd., 2006.

[8] 3GPP, "3GPP TS 23.203 rel.7 - Policy and Charging Control Architecture," *3GPP Technical Specifications Group Services and System Aspects*, Sep. 2007.

[9] P. Calhoun et.al., "Diameter Base Protocol," *IETF RFC 3588*, Sept. 2003.

[10] 3GPP, "Technical Specification Group Core Network and Terminals; Policy and Charging Control (PCC) over S9 reference point," *3GPP TS 29.215*, May 2009.

[11] P. Weik, D. Vingarzan, T. Magedanz, "The FOKUS Open IMS Core - A Global Reference Implementation," *The IMS Handbook: Concepts, Technologies and Services*, pp. 113–132, Nov. 2008.

[12] D. Waiting, R. Good, R. Spiers, N. Ventura, "The UCT IMS Client," *Proc. 1st Open IMS Testbeds Workshop, colocated with Tridentcom '09*, 2009.

B iography

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