Toward Active Charging for Software Defined Wireless Networks

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Abstract. A programmable networking approach to charging for services in software defined wireless networks (SDWN) could greatly facilitate the service innovation that is anticipated therein. It would allow service differentiation through customized charging and would support the provision of composite services across multiple providers. In this position paper we consider how earlier approaches to active charging can be combined with the 3GPP charging framework and recent SDN inspired cellular architectural innovations to provide an active charging infrastructure for SDN. Our analysis shows that active charging in SDN is technically feasible, commercially beneficial and incrementally deployable.

1 Introduction

Software defined networking (SDN) has been one of the principal trends in networking in recent years. SDN facilitates network programmability i.e. the ability to dynamically load software programs into network nodes in order to implement new features or modify existing capabilities. The combination of network programming and network virtualisation– including network function virtualisation (NFV)– promises of great service innovation. Service providers' will spin up virtual networks on demand to provide new end-to-end services. Network service providers also will have opportunities to quickly create new services through the convergence of network and cloud computing. Programmability will enhance collaboration between network providers and OTT service providers to provision loosely coupled composite services combining network and OTT services. Flexible service composition will require equally flexible charging support in the network service providers operation and business support systems (OSS/BSS) as e.g. in the recent the suggestion to allow content providers to cover usage charges for mobile subscribers, [1]. Service providers will seek to provide tailored billing perhaps even on a subscriber level.

It is our contention that programmable networking can greatly facilitate the provision of flexible charging schemes for both composite services and virtual network based value added services. Current charging systems are not however geared to meet these challenges, not least of which because they assume a very network operator centric view of the world. However the idea of a programmable/active networking charging infrastructure is not an unobtainable vision. Rather, the combination of recent SDN inspired cellular architecture proposals [1], active charging proposals, [16, 17]

R. Giaffreda et al. (Eds.): IoT360 2014, Part II, LNICST 151, pp. 248–253, 2015.
DOI: 10.1007/978-3-319-19743-2_35

and current charging systems, [6, 7], provides a firm base for development of such a charging infrastructure - how to do so is the subject of the remainder of the paper.

A novel proposal (SoftCell) to re-architect the cellular core network architecture based on use of SDN principles is outlined in [1]. The key thrust of this proposal is that "*The network should consist of a fabric of simple core switches, with most functionality moved to low-bandwidth access switches (at the base stations) and a distributed set of middleboxes that the carrier can expand as needed to meet the demands, A logically-centralized controller can then route traffic through the appropriate middle-boxes,* via *efficient network paths, to realize a high-level service policy*". A "high level service policy" is based on subscriber and application attributes including network provider, device type, subscriber type etc. Another suggested extension is to provide 'local software agents' in the switches to perform simple actions such as polling counters and comparing against thresholds. This re-architecting will help provide for more fine-grained and real-time monitoring and accounting. The capability to provide flexible high-level policies will also allow for a more active and flexible approach to charge calculations. Another factor that motivates our approach is the potential to place policy agents on mobile devices for applications such as mobility control [3], or charging based on dynamic pricing [2].

The rest of this paper is structured as follows: Sect. 2 describes current network charging concepts– in particular those for 3GPP. It also outlines previous research efforts addressing charging for composite services. Section 3 describes prior research on active charging while Sect. 4 combines these different threads to show how an active charging infrastructure can be derived for SDN based wireless network. Finally Sect. 5 outlines our conclusions.

2 Charging Concepts

A definition of charging is given in the 3GPP standards, [8] as the "*function ....whereby information related to a chargeable event is collected, formatted, transferred and evaluated in order to make it possible to determine usage for which the charged party may be billed*".

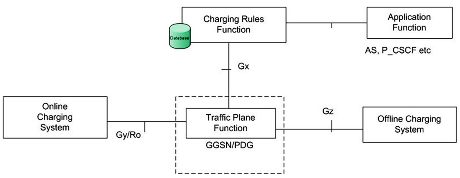

Fig. 1. 3GPP Charging Architecture

Figure 1 above (from [4]) depicts the (flow-based) 3GPP charging architecture (including the interface types of which specific details can be found in [7])

The Traffic Plane Function (TPF) monitors the usage of resources under its control and generates charging (or accounting) information when a chargeable event occurs.. Processing of the consequent charging event to yield a cost for resource usage may take-place in online or offline modes. In the online case charging takes places in real-time. The TPF must check with the Online Charging System (OCS) before allowing resource usage. The OCF is the central function and coordinates the overall charging process. Typically it assigns an initial quota for resource usage in the CTF and initiates re-authorisation to extend the session if needed.

Flow based charging is an extension of the charging system to enable service specific charging on the bearer i.e. flow level. It is realised by a combination of the TPF, the Charging Rules Function (CRF) and the Application Function (AF) [7]. The CRF decides which rules to apply based on resource information from the TPF and session and media information received from the AF. The TPF is configured based on policies called charging rules which are contained in the CRF. i.e. the CRF installs filters on the TPF to enable it to identify the service session flows. The AF provides the services for which flow based charging occurs.

The flow-based charging physical architecture has changed evolved over time. In the first evolution charging control and resource policy control (gating and QoS control) have been combined into the Policy and Charging Control (PCC) functions. The TPF has evolved to become a Policy and Charging Enforcement Function (PCEF) and the CRF has evolved to become the Policy and Charging Rules Function (PCRF). Since Release [11, 7], the Traffic Detection Function (TDF) has been introduced to apply policy and charging for "over the top" (OTT) services i.e. Internet services which are not provided by an AF e.g. Skype or Netflix. The TDF is essentially a deep packet inspection network element and may be implemented stand-alone or integrated with a PCEF.

In the *composite service* delivery model service components may be provided by different service providers and the (composite) end-user service is provided by a federation of different service providers with one provider acting as an overall service aggregator or broker. Charging for such services is complicated by the need to coordinate charging across different providers, to correlate charging identifiers and to consider context based charging i.e. the tariff to be applied for a component may depend on the components/service provider it is used with to provide the overall service.. Most researchers in this area, [5, 9], assume a post-paid charging while Van Le, [10] investigates how on-line charging can be applied to composite services.

3 Active Charging

Active charging entails the placement of an "active tariff" in the network to calculate the cost in real time. This contrast to the 3GPP case where policy based accounting is employed to monitor resource usage.

One approach to active charging based on "active tariffs" is described in [11], which proposed to push all accounting and charging onto end-user hosts, Charging is on a per packet basis and tariffs, which are Java objects, are disseminated to end-users via multicast, where each multicast group corresponds to a network service. The provider can access the users machines remotely and generate billing reports at a range of temporal frequencies. The system can be used for dynamic pricing where prices are matched to network state– see also [2].

In [12] the author describes a real-time charging approach based on a combination of active networking and policy management. The work describes (i) a charging functional reference model and (ii) a programming language (APPLE) for the definition of charging programs and policies and (iii) and an runtime execution environment (PEACH) to enable charging program execution. PEACH is focused on charging only i.e. it assumes accounting functions exist already. The APPLE language enables both the definition of (passive) charging schemes and tariffs via a *Rule* construct as well event-driven active rating logic via a *Module* construct. The reference model describes interaction between the traffic session agent and a related charging session agent function (CSA), which in turn is comprised of a number of sub-functions. The *charge analysis function* (CAF) is a policy server and contains the policies to determine how charging should be handled for a particular service. The *charge session coordinator (*CCP*)* is stateful and event driven and coordinates the charging for particular service session. The *charge execution point* (CEP) carries out the actual charging for a particular service i.e. executes an active tariff to calculate the charges for a session. The CEP periodically outputs the calculated charges towards a *charge accumulation point* (CAP).

PEACH in fact supports runtime mobility of modules between nodes which would enable a charging session to follow the end-user or enable migration of the session state to/from an end-user terminal. PEACH is intended to be a flexible framework to support arbitrary service models and hence may be deployed in many configurations e.g. for a particular service there could be a number of CEP or the CSA could be duplicated across multiple service providers. It can quite easily support the requirements for flexible, customizable charging schemes and loosely coupled composite OTT service charging as described in the opening chapter through allowing embedding of OTT service provider charging logic inside the service provider network– unlike the composite charging systems described in the previous chapter which all assume a tightly coupled composite charging tree rooted at a service broker/aggregator.

4 Application to SDN

The extensive use of policy based approaches in SDN, [8], taken together with the cellular architecture in [1] suggest a synergistic overlap of SDN and LTE to evolve current systems towards active charging.

In the first phase SDN can move toward a ‘policy based accounting’ architecture based on the functional changes suggested in [1]. New functions on the controller include the ability to specify flexible policies based on subscriber attributes -including e.g. network provider, subscriber type etc.– and a subscriber information base that stores and maintains subscriber information. The switches in turn also contains new functions such as a local ‘software agent’ that performs limited local computation -such as counter thresholding– deep packet inspection (DPI) and header compression.

It is possible to frame these proposals in a 3GPP charging architecture context. The new high level policy module may be seen as 'porting' the PCRF to an SDN controller. The associated subscriber information base corresponds, in part at least, to the 3GPP Subscriber Profile Repository (SPR). The proposed switch changes support the inclusion of the Traffic Plane Function (TPF) in the switches. The net effect of these changes is to introduce distributed policy based accounting to SDN. (Although described in the context of cellular i.e. LTE networks these innovations may have of course a broader application in other SDN domains also.) Exactly how these new controller charging modules would interact with each other and other controller modules is an open question as is exactly which functions would be controller based or external applications that interact with the controller over a north bound interface.

One can extrapolate this distributed accounting approach to envisage the placement of TPF functionality on the mobile device itself. By and large the technologies to do so are present today already – certainly the mobile devices contain the required computational and software capabilities.

A starting point in toward active charging is to consider the overlap of the PEACH active charging reference model on the proposed phase one accounting architecture just discussed. The PEACH charge analysis point (CAP) corresponds to the rating function of the OCS. The charge coordination (CCP) corresponds to the online charging function (OCF) OCS component. It is clearly a network level function and thus can be seen as an SDN controller module. The charge execution (CEP) on the other hand is intended to be distributed to the network elements in a manner as envisaged by the switch local agents - the inclusion of DPI in the switches providing extra support also. Following the argument above the CEP could also be migrated to mobile devices as well. However the CEP is foreseen to be an active charging element i.e. the CEP is a computer program and requires an execution environment. In the PEACH architecture the CEP effectively executes a rating rule and calculates a charge which it outputs towards a charge accumulation point (CAP). This is in contrast to the 3GPP approach which maps the rating into a resource usage threshold which is then monitored. From a programming model and distribution perspective PEACH and 3GPP policy and charging are towards opposite ends of the spectrum and SoftCell provides an important architectural bridging step on the road toward active charging. We can also anticipate that some programming model aspects of both approaches will appear in an evolved active charging environment e.g. PEACH may adopts the 3GPP resource limit approach rather than compute the charge on each event. There are of course many challenges and open questions to be answered to design and deploy such a system. These include (but are not limited to):

- *Detailed architecture design*: - Much more work is needed to understand charging requirements– both functional and non functional in order to decide the optimal design and placement of active charging logic.
- *Effects of NFV:* - NFV can certainly be considered as an enabler for active charging- exactly how remains to be investigated.
- *Programming models and execution environments*: Languages such as Frenetic and Pyretic, [8], support formulating policies in subscriber relevant terms rather than

lower level network. More work is required to understand the charging needs in order to see if current solutions suffice or if totally new approaches are needed.

5 Conclusion

We have described active charging approach for SDN which is based on a combination of a proposed SDN based cellular network core architecture, 3GPP online charging and a previous active charging proposal. We have shown how an active charging infrastructure can be incrementally deployed and have illustrated service scenarios which can benefit from active charging.

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