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ENHANCED PROBE BASED ADMISSION CONTROL SYSTEM FOR TRAFFIC OFFLOADING

[#1]MAILARAM KAVERI, M.Tech Student,
[#2]R.PADMA, Associate Professor,
Dept of CSE,
MOTHER THERESSA COLLEGE OF ENGINEERING & TECHNOLOGY, KARIMNAGAR, T.S.,INDIA.

ABSTRACT: Cellular networks are currently facing severe traffic overload problems caused by excessive traffic demands. Offloading part of the cellular traffic through other forms of networks, such as Delay Tolerant Networks (DTNs) and WiFi hotspot, is a promising solution since these networks can only provide intermittent connectivity to mobile users, utilizing them for cellular traffic offloading may result in a non negligible delay. As the delay increases, the users' satisfaction decreases. we investigate the tradeoff between the amount of traffic being offloaded and the users' satisfaction. We provide a novel incentive framework to motivate users to leverage their delay tolerance for cellular traffic offloading To minimize the incentive cost given an offloading target users with high delay tolerance and large offloading potential should be prioritized for traffic offloading To effectively capture the dynamic characteristics of users' delay tolerance our incentive framework is based on reverse auction to let users proactively express their delay tolerance by submitting bids. The explosive traffic demands and limited capacity provided by the current cellular networks, Delay Tolerant Networking (DTN) is used to migrate traffic from the cellular networks to the free and high capacity device-to-device networks. Since these networks can only provide intermittent connectivity to mobile users, utilizing them for cellular traffic offloading may result in a non-negligible delay. In this paper, we proposing a novel technique called dynamic cellular offloading to enable a cellular service provider to purchase and leverage third-party resources on demand through reverse auctions. Dynamic cellular offloading has several important features like explicit spatial coverage of different users, dynamic nature of traffic demands, effective truth valuation in bidding process. With this technique, we are using optimal algorithm to determine the optimal solution that minimizes the incentive cost during traffic offloading. Our trace-driven simulation shows that this method effectively reduces cost and is robust against collusion. Our prototype implementation demonstrates its feasibility.

Keywords*— Cellular traffic offloading, Delay Tolerant Networking (DTN), WiFi hotspots.*

I. INTRODUCTION:

Existing offloading studies have not considered the satisfaction loss of the users when a longer delay is caused by traffic offloading. Not considered the satisfaction loss of the users when a longer delay is caused by traffic offloading. Only provide intermittent and opportunistic network connectivity to the users. Non-negligible data downloading delay. In this paper, we focus on investigating the trade-off between the amount of traffic being offloaded and the users' satisfaction, and propose a novel incentive framework to motivate users to leverage their delay tolerance for traffic offloading. Users are provided with incentives; i.e., receiving discount for their service charge if they are willing to wait longer for data downloading. During the delay, part of the cellular data traffic may be opportunistically offloaded to other networks mentioned above, and the user is assured to receive the remaining part of the data via cellular network when the delay period ends. To motivate the mobile users with high delay tolerance and large offloading potential to offload their traffic to other intermittently connected networks such as DTN or WiFi hotspots. To capture the dynamic characteristics of users' delay tolerance. To predict users' offloading potential based on their mobility patterns and the geographical distribution of WiFi hotspots in the WiFi case.

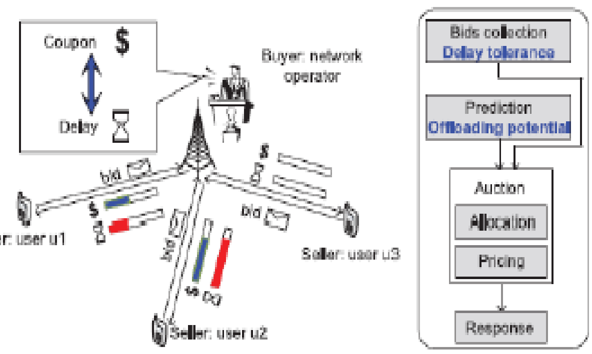

Fig 1: Cellular Traffic

Motivation. The advent of sophisticated handheld communication devices, such as smart phones and tablets, has substantially enriched the mobile user experience by expanding the reach of services such as social media applications and multimedia content delivery to the mobile domain. This, in turn, has fuelled a tremendous growth of global mobile data traffic, which is expected to increase 10x times until year 2019 [1] and threatens to drain the capacity of cellular networks. These developments herald the advent of a new era in communication networks, with novel challenges for content delivery over wireless networks. Namely, in order to satisfy the content requests of mobile users (MUs), it is required to ensure high capacity at the wireless access network and increased availability of the content items which should be placed in close proximity to the requesters. To address the first issue, mobile network operators (MNOs) upgrade their technology (e.g., from WCDMA to LTE-A) and deploy small cell base stations (SBSs) such as microcell, piccolo and femtocell base stations. These SBSs are connected to the core network through backhaul links and operate in conjunction with the microcellular base stations (MBSs), yielding the so-called heterogeneous cellular networks (HCNs). The short-range SBS transmissions incur less energy consumption compared to the transmissions of the MBS and allow for spectrum reuse. On the second issue, recently there is an increasing interest for novel architectures where MNOs cache at certain SBSs popular content items for which recurring requests are expected [2], [3]. Recent field evaluations of such systems revealed 45% reduction of backhaul traffic and 22% savings in other operating expenditures [4], while at the same time the mobile user experience is improved. Interestingly, the wireless network industry has already begun to commercialize systems that enable caching at the SBSs [5].

Never the less, the deployment of additional base stations still requires significant capital investments (CAPEX), and induces high operational expenditures (OPEX) due to power consumption, bandwidth cost of the backhaul links, etc. Also, the ubiquitous deployment of this equipment is extremely daunting and even impractical in many cases (e.g., due to site acquisition issues). More importantly, as the user mobility patterns and content preferences dynamically change over time, the initial base station deployment may become inefficient to fulfill its scope. For example, a market mall may close resulting to a drastic reduction of local traffic, hence rendering cost-inefficient the nearby deployed base stations.

At the same time, an increasing number of residential subscribers of the MNOs install in their premises SBSs, such as femtocell access points (FAPs) or WiFi access points (APs), in order to serve their own needs. Clearly, these base stations can serve also other subscribers of the MNO (the MUs) which lie in their coverage area. Even better, these SBSs can cache in advance in their available storage repositories popular files and deliver them to the MUs upon request. This appears to be a promising approach, as recent measurement studies [6], [7] revealed that residential wireless networks are often underutilized. More importantly, these studies indicated those residential and mobile users' traffic follow diverse spatiotemporal patterns, suggesting that the latter could utilize the idle network resources (SBSs) of the former. Hence, there is an opportunity for the MNOs to lease wireless bandwidth and storage resources of underutilized residential SBSs, so as to serve their mobile users.

However, since the SBSs are managed by their self interested owners, the MNO must offer to them proper (monetary) compensation in order to agree to cache and deliver the requested content to the MUs. The amount of compensations depends on the caching and routing policy the MNO will employ so as to serve his mobile users. In particular, the MNO needs to jointly derive: (i) the incentive policy: how much to reimburse each SBS owner and for how much resources, (ii) the caching policy: in which SBSs to cache each content item, and (iii) the routing policy: in which SBS to route each user's request for each content item. Clearly, caching and routing policies are constrained by the amount of the leased SBS resources. Besides, a content item can be delivered to a mobile user only if the latter has access to an SBS that has cached this specific item.

II. RELATED WORK

In this section, we briefly overview the related works on infrastructure-based mobile traffic offloading, ad-hoc-based mobile traffic offloading, and the utilization of green energy in cellular networks.

A. Infrastructure-Based Mobile Traffic Offloading

In infrastructure-based mobile traffic offloading, the mobile traffic is offloading to either pico/femto BSs or WiFi hot spots. Deploying pico/femto BSs improves the spectral and energy efficiency per unit area of cellular networks, and thus reduces the network congestion and energy consumption of cellular networks. Traffic offloading between pico/femto BSs and the MBS is achieved by adapting the user-BS associations. Kim et al. [5] proposed a user-BS association to achieve flow level load balancing under spatially heterogeneous traffic distribution. Jo et al. [6] proposed cell biasing algorithms to balance traffic loads among pico/femto BSs and theMBS. The cell biasing algorithms perform user-BS association according to the biased measured pilot signal strength, and enables the traffic to be offloaded from the MBS to pico/femto BSs. WiFi hot spots are also effective in terms of offloading mobile traffic. Lee et al. [7] pointed out that a user is in WiFi coverage for 70% of the time on average, and if users can tolerate a 2 h delay in data transfer, the network can offload about 70% cellular traffic to WiFi networks. Balasubramanian et al. [8] proposed to offload the delay tolerance traffic such as email and file transfer to WiFi networks. When WiFi networks are not available or experiencing blackouts, data traffic is fast switched back to 3G networks to avoid violating the applications' tolerance threshold. Han and Ansari [9] designed a content pushing system which pushes the content to mobile users through opportunistic WiFi connections. The system responds to a user's pending requests or predicted future requests, codes these requested contents by using Fountain codes, predicts the user's routes, and prelocates the coded contents to the WiFi access points along the user's routes. When the user connects to these WiFi access points, the requested contents are delivered to the user via the WiFi connections.

B. Ad-hoc-Based Mobile Traffic Offloading

Ad-hoc-based mobile traffic offloading rely on D2D communications to disseminate contents. Instead of downloading contents directly from BSs, UEs may retrieve contents from their neighboring UEs. Han et al. [10] proposed a mechanism to select a subset of UEs based on either UEs' activities or mobilities, and Let these UEs further disseminate the contents through D2D communications to the other users. Mashhadi and Hui [11] proposed a proactive caching mechanism for UEs in order to offload the mobile traffic. When the local storage does not have the requested contents, the proactive caching mechanism will set a target delay for this request, and explores opportunities to retrieve data from the neighboring UEs. The proactive cache mechanism requests data from cellular networks when the target delay is violated. To encourage mobile users participate in the traffic offloading, Zhou et al. [12] proposed an incentive framework that motivate users to leverage their delay tolerance for cellular data offloading.

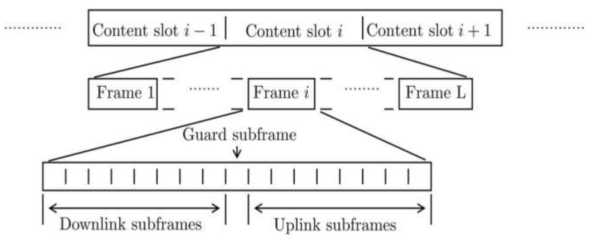

Fig. 2. Content slot structure.

C. Utilization of Green Energy

Green energy techniques, in which green energy such as sustainable biofuels, solar, and wind energy is able to power BSs, can save on-grid energy consumption of BSs and reduce the footprints [13]. Ericson Inc. [14] has developed a wind-powered tower for BSs of cellular networks. To optimize the utilization of renewable energy, Zhou et al. [15] proposed the Hand Over (HO) parameter tuning algorithm and the power control algorithm to guide mobile users to access the BSs with renewable energy supply. Han and Ansari [16] proposed an energy aware cell size adaptation algorithm named intelligent cell breathing (ICE), which balances the energy consumption among BSs powered by green energy, and enables more users to be served with green energy. Considering a network with multiple energy supplies, Han and Ansari [17], [18] also proposed to optimize the utilization of green energy, and reduce the on-grid energy consumption of cellular networks by the cell size optimization.

III. OVERVIEW

1. The Big Picture

In this section, we give an overview of the Win-Coupon framework. By considering the users' delay tolerance and offloading potential, Win-Coupon uses a reverse auctionbased incentive mechanism to motivate users to help cellular traffic offloading. Fig. 1 illustrates the main idea. The network operator acts as the buyer, who offers coupons to users in exchange for them to wait for some time and opportunistically offload the traffic. When users request data, they are motivated to send bids along with their request messages to the network operator. Each bid includes the information of how long the user is willing to wait and how much coupon he wants to obtain as a return for the extra delay. Then, the network operator infers users' delay tolerance. In addition, users' offloading potential should also be considered when deciding the auction outcome. Based on the historical system parameters collected, such as users' data access and mobility patterns, their future value can be predicted by conducting network modeling, and then based on the information, users' offloading potential can be predicted.

During the delay period, u1 may retrieve some data pieces from other intermittently available networks, for example, by contacting other peers that cache the data or moves into the wireless range of APs. Once delay t passes, the cellular network pushes the remaining data pieces to u1 to assure the promised delay. The losing bidders (e.g., user u3 shown in Fig. 1) immediately download data via cellular network at the original price.

2. 3.2 User Delay Tolerance

With the increase of downloading delay, the user's satisfaction decreases accordingly, the rate of which reflectsthe user's delay tolerance. To flexibly model users' delay tolerance, we introduce a satisfaction function S(t), which is a monotonically decreasing function of delay t, and represents the price that the user is willing to pay for the data service with the delay. The satisfaction function is determined by the user himself, his requested data, and various environmental factors. We assume that each user has an upper bound of delay tolerance for each data. Once the delay reaches the bound, the user's satisfaction becomes zero, indicating that the user is not willing to pay for the data service.

3. Auctions

In economics, auction is a typical method to determine the value of a commodity that has an undetermined and variable price. It has been widely applied to many fields. Most auctions are forward auction that involves a single seller and multiple buyers, and the buyers send bids to compete for obtaining the commodities sold by the seller. In this paper, we use reverse auction [19] that involves a single buyer and multiple sellers, and the buyer decides its purchase based on the bids sent by the sellers. To begin with, we introduce some notations: Bid(bi): It is submitted by bidder i to express i's valuation on the resource for sale, which is not necessarily true. Private value(xi): It is the true valuation made by bidder i for the resources, i.e., the true price that i wants to obtain for selling the resource. This value is only known by i. Market-clearing price(pi): It is the price actually paid by the buyer to bidder i. This price cannot be less than the bids submitted by i. Utility(ui): It is the residual worth of the sold resource for bidder i, namely the difference between i's market-clearing price pi and private value xi. The bidders in the auction are assumed to be rational and risk neutral. A common requirement for auction design is the so-called individual rationality.

4. Preliminaries on auction theory

In this section, we briefly overview the concept of auctionsand some relevant terms and notations.In economics, an auction is a typical method to determinethe value of a commodity that has a variable price. Mostauctions are forward auctions which involves a single seller andmultiple buyers. In this paper, we use a reverse auction in the Single MUE scenario, which involve a single buyer (MUE) andmultiple sellers (femtocells). The sellers compete for selling thecommodities by submitting bids, then the buyer decides on itspurchase. In addition, we use a double auction in MultiMUEscenario, where multiple buyers and sellers are included. Theysubmit bids and asks to the auctioneer, who decides the result.The notation is introduced below.bid (bi): the valuation of the resource submitted by bidder i,which is not necessarily true. An ask (ai) of a seller in a double auction is defined similarly. Private Value (vi): the true valuation for the resource by bidder i. This value is only known by the bidder. Price (pi): the price actually paid by the buyer i (or paid tothe seller i). Utility (ui): the residual value of the resource. For buyer i, it is ui = vi pi, while for seller i, it is ui = pi vi. Individual Rationality: An auction is individual rational if allbuyers and sellers are guaranteed to obtain non-negative utility.It is a common requirement for auction designs.

IV. CONCLUSION

In this paper, we proposed an incentive framework to motivate femtocells to open their access to unregistered MUEs, which help increase network capacity and offload traffic. We carefully designed the VCG-based auction mechanisms to allocate access times and rigorously proved that all the participating agents can truthfully cooperate. Simulation results demonstrate that the performance of MUEs can be significantly improved, with system efficiency maximized in auctions. In the future, we plan to study the incentive issue of femtocells controlled by different operators, Hence, we need to design other offloading strategies and the prediction methods for the DTN case.

To capture the dynamic characteristics of users' delay tolerance, we design an incentive mechanism based on reverse auction. Our mechanism has been proved to guarantee truthfulness, individual rationality, and low computational complexity.

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