様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

平成　３０　年　　６　月　２２　日現在

機関番号：　３２６１３
研究種目：　若手研究(B)
研究期間：　2016～2017
課題番号：　１６Ｋ１６０５１

研究課題名（和文）Intelligent Bandwidth Consumption Scheduler Considering WiFi/Femtocell Connectivity and Users' Preferences with Dynamic Pricing

研究課題名（英文）Intelligent Bandwidth Consumption Scheduler Considering WiFi/Femtocell Connectivity and Users' Preferences with Dynamic Pricing

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交付決定額（研究期間全体）：（直接経費）　　1,900,000円

研究成果の概要（和文）：本研究では，通信速度をリアルタイムに可視化するサービスが提供されることを前提として，帯域幅消費スケジューラの設計と実装について検討を行った．セルラーネットワークに輻輳が起きた場合に，スケジューラはユーザの便益を考慮し，トラフィックをオフピーク時間にシフトさせるか，無線LAN /フェムトセルネットワークにオフロードするか，またはそのまま維持するか，適切な判断を行う．また,その際にユーザの便益を定義するために,利用可能帯域幅や待ち時間に対するユーザの支払意思額関数を用いた．ピーク時の輻輳が効率的に緩和されることが分かった．

研究成果の概要（英文）：This research focuses on the design and implementation of an intelligent bandwidth consumption scheduler considering WiFi/femtocell connectivity and users’ preference with dynamic pricing, aiming at mitigating the peak-time congestion. Following the task profile consists of actuation time, operation length, maximum budget for cellular usage, delay tolerance etc., the scheduler makes decisions on either shifting the delay-tolerant traffic to off-peak time or offloading the traffic to WiFi/femtocell networks dynamically, which on the other hand empowers users with the choice of saving on their monthly bills. We built up a proof-of-concept android system and conducted experiment to verify the efficiency of our proposed scheduler. Results show that the peak-time congestion could be efficiently alleviated.

研究分野：　通信・ネットワーク工学

キーワード：　offloading　peak time　pricing

１．研究開始当初の背景

The mobile data traffic is expected to reach 24.3 exabytes per month by 2019, while it is only 2.5 exabytes per month at the end of 2014. In order to cope with the explosive growth of data traffic, wireless service providers (WSPs) struggle to enlarge their network capacities by installing new cell towers and offloading cellular data traffic to supplemental networks (such as WiFi and femtocells).

Furthermore, WSPs also explore the use of economic incentives to mitigate congestions. Since May 2011, American ISPs T-Mobile and AT&T start data caps and throttle penalty for additional usage per month, which is termed usage-based pricing (UBP). UBP is effective in limiting monthly data usage for contract users, but ineffective in reducing peak-time congestion unless it dynamically changes its prices reflecting network congestion levels. Time-dependent pricing (TDP) addresses the peak-time congestion problem by considering when a user consumes data, in addition to how much a user consumes data. The first demo system of a TDP scheme is named TUBE, where ISP offers prices on a day-ahead basis. Price changes every 30 minutes depending on the historical information of traffic load. In [3], the authors propose a fixed-budget rebate mechanism that gives each user a reward proportional to his percentage contribution to the aggregate reduction in peak-time demand.

It can be foreseen that in a near future: (i) more and more free supplemental networks will be available; and (ii) pricing schemes will be more and more dynamic. As a consequence, in order to get higher benefit, users have to monitor the connectivity of supplemental networks as well as the change of prices and make traffic offloading or shifting decisions accordingly. To the best of our knowledge, there is no widely accepted framework that assists users to schedule the use of network considering WiFi/femtocell connectivity, dynamic changing prices, and users' preferences.

２．研究の目的

We focus on proposing a framework that can assist users to schedule their bandwidth consumption intelligently. As shown in Figure 1, User Interface interacts directly with users, displaying the dynamic pricing information, the billing information, the offloading/shifting decisions made, and notifications for launching applications when free WiFi/femtocell is available (or when price is relatively low), etc. Users may set their preferences as well, for example, the maximum budget for cellular usage, data caps, priority of different applications, as well as delay tolerances for different applications. The Bandwidth Consumption Scheduler then makes traffic offloading or shifting decisions for the user, given the preferences set on the user interface. The Bandwidth Consumption Scheduler consists of two components: the Mobility Pattern Predictor, and the WiFi/Femtocell Connectivity Predictor. The Mobility Pattern Predictor predicts the time-dependent location of a user with the help of GPS, and WiFi/Femtocell Connectivity Predictor predicts the availability as well as the time-dependent throughput within a geographical range.

The main objectives of this research are summarized as follows:

We try to optimize traffic offloading or shifting decision making based on predicted location and WiFi/femtocell connectivity information, price information, as well as preferences set by users.

We seek to understand how users tradeoff between the cost of cellular data usage and their willingness to delay.

We try to understand the characteristics of applications that are more likely to be scheduled.

We implement system for proof-of-concept experiments. We evaluate to what extent an intelligent bandwidth consumption scheduler can save on users' bills while satisfying their QoS requirements. We also evaluate the battery consumption cost when adopting the intelligent scheduler.

３．研究の方法

Toward the "Intelligent Bandwidth Consumption Scheduler Considering WiFi/Femtocell Connectivity and Users' Preferences with Dynamic Pricing", we research and develop the components as mentioned in the previous Section one by one.

Survey: We conduct a detailed survey of the related work such as the state-of-the-art bandwidth consumption scheduler for traffic offloading and shifting. By conducting this survey, we could have a better understanding of this filed to promote the following research and implementation.

Real System Implementation: After

solving all the technical problems, we will investigate how our proposed algorithms can be implemented in real-time inside a commercial wireless network. This part is done with the collaboration of our co-researchers at North China Electric Power University (NCEPU), China.

Supplemental Network Connectivity Predictor: Since WiFi/femtocell availability and throughput is heavily location-dependent, we predict the probabilities of WiFi/femtocell availability and the average throughput by combining user location prediction with the probabilities of WiFi/femtocell availability and average throughput at different locations. We use a training set of empirical data to estimate time-dependent WiFi/femtocell availability and throughput at each location, which are updated on a timely basis.

４．研究成果

Eight journal papers have been published/accepted by IEEE Access, IEEE Vehicular Technology Magazine, ACM/Springer Mobile Networks and Applications, IEEE Network, Transactions on Emerging Telecommunications Technologies, and IEICE Transactions on Communications. Researchresults have been presented at 15 international conferences, including IEEE GLOBECOM 2017, CCNC 2017, and ICC 2018, where our work has been given complimentary remarks. Research results have also been presented at domestic conferences and symposiums for many times. Proof of concept system have been successfully built to verify the feasibility of the proposed system. Results show that the peak-time congestion could be efficiently alleviated.

５．主な発表論文等

（研究代表者、研究分担者及び連携研究者には下線）

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〔産業財産権〕

○出願状況（計　0件）

名称：
発明者：
権利者：
種類：
番号：
出願年月日：
国内外の別：

○取得状況（計　0件）

名称：
発明者：
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取得年月日：
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〔その他〕
ホームページ等
https://er-web.sc.kogakuin.ac.jp/Profiles/14/0001309/profile.html?lang=en

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