I-CAN: Information-Centric Future Mobile and Wireless Access Networks

George C. Polyzos, Vasilios A. Siris, George Xylomenos, Giannis F. Marias, and Stavros Toumpis
Mobile Multimedia Laboratory, Department of Informatics
School of Information Sciences and Technology
Athens University of Economics and Business, Greece
{polyzos, vsiris, xgeorge, marias, toumpis}@aueb.gr

Abstract—**This short paper describes the objectives and initial results of project I-CAN: Information-Centric Future Mobile and Wireless Access Networks. I-CAN seeks to radically advance the integration of cellular and wireless access technologies by developing and evaluating architectures and procedures for future access networks based on Information-Centric Networking (ICN).**

Keywords-component; Future Internet; heterogeneous wireless access; integration of mobile and wireless networks

I. INTRODUCTION

Mobile traffic in 2013 grew by 81%, becoming nearly 18-times the global Internet traffic in 2000, and is expected to grow 10-fold from 2013 until 2018[1]. A promising solution to address the strain from the exponential growth of mobile traffic is to move a portion of it to Wi-Fi networks, exploiting the existence of multiple wireless interfaces in smartphones (i.e., both 3G/4G and Wi-Fi) and the significantly lower cost of Wi-Fi technology. At the same time, the Internet's current dominant usage model involves end-users exchanging information or accessing services, independently of the device that provides them. Moreover, not only the consumption but also the production of content is becoming user-centric, requiring a network infrastructure that facilitates the efficient delivery of user-generated content, and considering the connectivity and energy constraints of mobile sources.

The goal of the I-CAN project is to develop and evaluate architectures and procedures for future access networks based on Information-Centric Networking (ICN) in order to radically advance the integration of cellular (licensed spectrum) and wireless (license-exempt) access technologies. ICN decouples the data from the actual devices storing it through the location-independent naming of content. This decoupling presents a fundamental departure from the Internet's host-centric communication model, towards an architecture that matches the Internet's current dominant usage identified above.

Content-awareness along with the decoupling of content creation, advertisement, and transfer, offers opportunities for enhancing both receiver and content mobility. The delay tolerance of mobile social network applications and user-generated data delivery offer a wider range of tradeoffs between delay, energy efficiency, amount of offloaded traffic, and cost. For user-generated content, mobile sources can announce the availability of content, deferring its actual transfer until more cost and energy efficient connectivity options become available. An additional benefit from retaining the actual information at the mobile source is improved privacy and access control from the content producer.

The possibility of ubiquitous in-network caching, which is inherent to ICN due to its explicit naming of content rather than communication endpoints, opens up many opportunities for exploiting content-awareness in order to place information closer to the user. Moreover, by naming the content itself, ICN allows the receiver to obtain different parts of the content from different sources and through different paths. Optimizations in some of the above directions through overlay solutions to the current Internet are possible, but such solutions can be costly and are necessarily application-dependent. A key direction of ICN is to create a networking substrate that provides application-independent communication primitives that satisfy emerging information transfer and communication requirements, thus facilitating a more efficient and timely development of distributed data sharing applications, which is crucial for future innovations in the mobile space.

II. KEY RESEARCH DIRECTIONS AND INITIAL RESULTS

In this section we discuss the key research directions and some initial results of the I-CAN project.

A. Information-Centric Architecture for Integrating Mobile and Wireless Access Technologies

Previous ICN architecture proposals, such as DONA [1], CCN [2], CURLING [3], PURSUIT [4], focus on the Internet core; see [5] for a survey. While some approaches identify opportunities offered by ICN for mobile networks, e.g. MobilityFirst [6] which uses flat names and addresses for supporting mobility, actual progress on applying ICN to mobile access networks remains quite limited. A key position of I-CAN is that the specific characteristics and cost structures of mobile and wireless access technologies, together with the requirements of mobile social networking and user/community-oriented data sharing applications, need to be taken into account in order to develop an ICN architecture that efficiently integrates heterogeneous access technologies. Overlooking their specific characteristics and cross-layer interactions can result in significant inefficiencies as demonstrated, e.g. by the signaling storms in cellular networks caused by the power

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013-2018, Feb. 5, 2014.

This research has been co-financed by the European Union (European Social Fund-ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF)-Research Funding Program: Aristeia II/I-CAN.

QSHINE 2014, August 18-20, RHODES, Greece

DOI 10.4108/icst.qshine.2014.256360

saving features of smartphones, even though smartphones produce significantly less data traffic compared to laptops.

B. Proactive caching exploiting mobility and content prediction in integrated cellular and Wi-Fi networks

The I-CAN project is investigating procedures that exploit connectivity schedules and mobility patterns to determine when and what to transmit over different access technologies, taking into account connectivity costs, power requirements, and the delay tolerance of applications, as well as distributed procedures for proactive caching in space (multiple candidate locations a mobile can move next) and time (multiple locations a mobile will consecutively visit along its route). Indeed, the explicit naming of content in ICN enables different parts of the requested information to be obtained from different sources or caches. Moreover, ICN's request model can be used to predict the content that will be requested and proactively cache it.

Initial results include procedures that exploit mobility prediction and proactive caching to enhance mobile data offloading for delay tolerant and delay sensitive file transfer [7] and trace-driven evaluation of the trade-offs in terms of percentage of offloaded traffic, transfer delay, and energy consumption [8]. When a mobile's route is not known precisely, mobility information can still be utilized for proactive caching, together with congestion pricing to efficiently utilize cache storage [9].

C. In-network caching and replication

The I-CAN project is investigating in-network caching for improving the performance and reducing the operational cost of mobile and wireless access networks. Ongoing work involves formulating the problem of jointly and efficiently utilizing storage, connectivity, and bandwidth resources in a variety of forms, using, among others, combinatorial and network optimization tools. Distributed, fast converging, provably optimal algorithms for solving these problems will be proposed and compared with existing heuristic approaches. The dynamic nature of content popularity will be factored in the formulations.

D. Multipath/multisource transport and traffic engineering

The project is investigating procedures for multisource and multipath transport and routing that exploit the inherent broadcast capabilities of mobile and wireless networks, while accounting for different energy and connectivity costs, and study how these procedures interact with in-network caching and content replication. Furthermore, since mobiles can have multiple wireless interfaces attached to different access networks, multipath transport and traffic engineering will need to be incorporated into the overall framework of an integrated cellular and Wi-Fi access network.

Initial results in this direction include the development of procedures for multipath/multisource transport over Publish-Subscribe ICN architectures [10]. Other work investigates procedures for multipath/multisource transport, combined with proactive caching, for improving the QoE and resilience of mobile video streaming [11].

E. Privacy support in ICN

The project is investigating novel solutions for both producer and consumer privacy. For producer anonymity, trusted intermediates, such as variations of mixnets or Tor [12], and global replication and oblivious storage services, such as Freeheaven [13], can be used. A flexible and generic ICN access control scheme will be designed, allowing publishers to dynamically configure access rules for individual objects or collections, exploiting ICN's unique and location independent naming. For consumer anonymity, mechanisms to ensure query privacy or homomorphic encryption can be used [14]. Such schemes require efficient trust management, which is an issue when information is provided by caches. Name based trust [15] is proposed to address this issue among others. To reduce privacy overhead, privacy-enhancement middleware, such as anonymous and mixing proxies, will be considered, rather than end-to-end encryption schemes. Finally, a framework for the privacy analysis of ICN architectures is being developed [16] to provide a structured analysis of the issue.

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