Dynamic capacity planning of wireless networks using user mobility behavior in smart cities

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***Abstract*— Smart cities are envisioned as the organic integration of systems to provide valuable information for its citizens and service providers. One such example is user mobility behavior information (use of user location data) related to wireless network consumption and demands. In this paper, we propose the use of this data in a novel manner for capacity planning purposes in wireless networks. We approach fifth generation (5G) capacity planning by considering Cloud Radio Access Networks and Software Defined Mobile Networks to improve dynamic resource allocation. Privacy concerns are also addressed.**

Keywords*— *smart cities; capacity planning; human mobility behavior; 5g; CSLI; C-RAN; SDMN; privacy; travel behavior; emergency; caching

I. INTRODUCTION

The Smart City can be defined as an organic connection among technological, human, and institutional components [1]. Each component is necessary but not sufficient in creating a smart city. For instance, the technological component (infrastructure of hardware and software) largely depends on the collaboration between industry, government, non-governmental organizations, educational organizations and citizens to be effective [2]. Although no framework can be broadly applied to every single city to assess a city's smartness [3], it is known that smartphones and mobile networks will play an important role to state and create this smartness.

Within the infrastructure required for such networks, a massive amount of spatio-temporal data can be sensed and collected as a by-product of its regular operation. This data called Cell Site Location Information (CSLI) includes the location of each mobile phone during voice calls, text messages, or data connections. Batty, et al., argue that this data will shape how we understand human mobility and will reveal unknown patterns of behavior in human daily activity [4].

While this has been used for urban planning, sustainable mobility, transportation engineering, public health, and economic forecasting [5, 6], no research could be found in the direction of capacity planning for cellular networks. Instead, decisions on capacity planning for cellular networks are made based on market analysis, customer requirements, environment factors, and other boundary conditions [7] and solely depend on the statistical knowledge of the area.

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II. THE FIFTH GENERATION (5G)

The Cloud Radio Access Network (C-RAN) virtualizes the Radio Access Network (RAN) to a singular virtual base station while performing load balancing, mobility, resource allocation, and other control functions in a single place [8]. This concept comes from Software-Defined Mobile Networks (SDMNs), where the control plane is detached from the data plane, empowering a centralized device to globally optimize the system based in the full network knowledge. This concept of Fifth Generation (5G) networks can be used to flexibly and dynamically access shareable spectrum and new bands [9]. It then becomes possible to use the CSLI with human mobility behavior prediction to dynamically change the capacity allocated to a base station at a certain time.

For example, a base station close to a university might have hundreds of users during the academic semester and a reduced number during holidays and vacation periods. Also, it is unlikely for users to be there during the night when the resources could be reallocated for residential districts. The same will apply for sports stadiums, shopping malls, highways and a large number of other locations. In those situations, channels from different frequency bands can be reallocated to meet those demands. And with frequency aggregation capabilities, 5G devices can combine those frequency bands to obtain the bandwidth they need.

Methods and patterns to predict human daily travel behavior can be borrowed from social science [10]. This will enable the estimation of when a certain user will be close to a certain base station and the required capacity. These models can also predict the types of data the users might need (voice, video, browsing, file transfer, etc.) and expected quality of service. Emergency users might have higher demands for reliability and immunity to congestion than other users [11].

III. PRIVACY CONCERNS

One of the concerns related to this approach is privacy. The U.S., regulations are still in development regarding sharing and using CSLI, but there is no limitation regarding the private use of this information [12]. Advanced research conducted by the European FET project GeoPKDD (Geographic Privacy-aware

Knowledge Discovery and Delivery) [4] has developed many analytical and mining methods for spatio-temporal data handling that can be used. Still, privacy is one of the major concern in 5G and Smart Cities, and needs to be addressed in future research [13].

IV. Conclusion

Capacity planning based on human mobility behavior provides great opportunities, and could even be expanded further for the benefit of smart cities. Optimized caching of content could be accomplished based on most likely user demands and predictions of their future locations. Delay sensitive information can be cached closer to users. For example, users on Wall Street may require stock market data with very small latency. Wireless network capacity planning is one of many research possibilities for using human mobility behavior in smart cities.

References

[1] T. Nam and T. A. Pardo, "Conceptualizing smart city with dimensions of technology, people, and institutions," in Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times, 2011, pp. 282-291.

[2] H. Lindskog, "Smart communities initiatives," in Proceedings of the 3rd ISOneWorld Conference, 2004, pp. 14-16.

[3] V. Albino, U. Berardi, and R. M. Dangelico, "Smart Cities: Definitions, Dimensions, Performance, and Initiatives," Journal of Urban Technology, vol. 22, pp. 3-21, Jan 2015.

[4] M. Batty, K. W. Axhausen, F. Giannotti, A. Pozdnoukhov, A. Bazzani, M. Wachowicz, et al., "Smart cities of the future," European Physical Journal-Special Topics, vol. 214, pp. 481-518, Nov 2012.

[5] K. W. Axhausen and T. Garling, "Activity-Based Approaches to Travel Analysis - Conceptual Frameworks, Models, and Research Problems," Transport Reviews, vol. 12, pp. 323-341, Oct-Dec 1992.

[6] A. Bazzani, B. Giorgini, L. Giovannini, R. Gallotti, and S. Rambaldi, "Now casting of traffic state by GPS data. The metropolitan area of Rome," in MIPRO, 2011 Proceedings of the 34th International Convention, 2011, pp. 1615-1618.

[7] A. R. Mishra, Advanced Cellular Network Planning and Optimisation : 2G/2.5G/3G - Evolution to 4G. Chichester: Wiley, 2007.

[8] A. Gudipati, D. Perry, L. E. Li, and S. Katti, "SoftRAN: Software defined radio access network," in Proceedings of the second ACM SIGCOMM workshop on Hot topics in software defined networking, 2013, pp. 25-30.

[9] T. Chen, M. Matinmikko, X. F. Chen, X. Zhou, and P. Ahokangas, "Software Defined Mobile Networks: Concept, Survey, and Research Directions," Ieee Communications Magazine, vol. 53, pp. 126-133, Nov 2015.

[10] N. Eagle and A. S. Pentland, "Eigenbehaviors: identifying structure in routine," Behavioral Ecology and Sociobiology, vol. 63, pp. 1057-1066, May 2009.

[11] C. Beard and W. Stallings, Wireless Communication Networks and Systems: Prentice Hall, 2016.

[12] L. H. Koh, "Order Affirming Denial of Application For Historical Cell Site Location Information," ed: United States District Court Northern District of California, 2015, pp. 1-46.

[13] X. Y. Duan and X. B. Wang, "Authentication Handover and Privacy Protection in 5G HetNets Using Software-Defined Networking," Ieee Communications Magazine, vol. 53, pp. 28-35, Apr 2015.