A System Dynamics Approach to Quantitatively Analyze the Effects of Mobile Broadband Ecosystem’s Variables on Demands and Allocation of Wireless Spectrum for the Cellular Industry

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ABSTRACT

Radio spectrum is an encumbered and finite resource. Perception of radio spectrum scarcity has been linked, sometimes linearly, to the higher demand of mobile data services and the greater market penetration of mobile broadband devices. Cellular operators worldwide have been asking to allocate more spectrum to support this demand. To validate the “spectrum scarcity” notion, various elements of the wireless ecosystem, including network infrastructure, spectral efficiency of mobile technologies, and data offloading via unlicensed spectrum need to be appraised; and their effects on “spectrum utilization” need to be understood. Research presented here takes a system dynamics approach to study dynamic behaviour among these elements and their effects on usage of spectrum through sensitivity analysis. A stock-and-flow model-based simulation is employed for hypotheses testing to justify the need for more spectrum. Simulation results show that mobile data demand can exceed the current capacity of cellular networks causing a spectrum deficit if apt planning of spectrum policies and appropriate infrastructure investment are delayed.

Keywords: Data Offloading, Goal Seek Behaviour, Mobile Data Demand, Spectrum Allocation, Spectrum Scarcity, Spectrum Utilization, Stock-And-Flow Modeling, Wireless Ecosystem

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INTRODUCTION

Mobile penetration rate – the number of cell phones per population – exceeds 100 percent in many countries (4GAmericas, 2011). There are more than 5 billion mobile phones in active use worldwide. In the United States (U.S.), a nine percent increase in the number of wireless subscribers in 2011 made the wireless penetration go above 100 percent. This number will reach 110 percent by 2015, making the total number of wireless subscribers rise to 360 million (TIA, 2012). The actual growth of subscribers may slow down as the penetration rate approaches 100 percent in many countries around the world, but wireless carriers’ cellular networks are becoming increasingly burdened due to higher use of internet-ready mobile phones (smartphones) and data-demanding applications such as online video and gaming.

Mobile-based voice traffic takes up far less of the capacity of the cellular network these days than does data traffic (RYSAVY, 2008). Most of the market studies conducted by leading analysts and industry professionals reveal that demand for mobile data will grow significantly over next few years. A recent study found that the average amount of traffic generated per smartphone per month in 2011 was 150 megabytes (MB), up from 55 MB per month in 2010 (Cisco, 2012). The study also projects that the global data traffic over mobile devices will increase by 18 times between 2011 and 2016. More people are expected to go online via mobile devices than personal computers by 2014 (MorganStanley, 2009). Increasing usage of smartphone devices along with the development of data-hungry applications which run on these devices are causing this surge of data demand on cellular networks. In fact, data consumption on smartphones is expected to grow from 0.3 GB per month to 3 GB per month in the next five years (RYSAVY, 2011).

To serve the public’s increasing need for accessibility of mobile data, that is wireless broadband, the cellular industry has been increasingly requesting more radio frequency spectrum to be released by regulatory bodies around the world. Terms like “capacity crunch” and “traffic tsunami” have been coined to indicate the dire need for more spectrum to support the growing demand of data services (ERICSSON, 2010). Radio spectrum translates directly to the speed of cellular networks in terms of bits per second available to each user. Spectrum and cellular networks’ capacity to handle more data services go hand in hand: the greater the amount of spectrum assigned to each cell site, the higher the spectral efficiency and speed of data services supported by the cellular networks (Berezdivin, Breinig, & Topp, 2002).

In the U.S., the Federal Communication Commission (FCC) made a recommendation through the National Broadband Plan that 300 MHz of new spectrum needs to be released in the next five years and 500 MHz over the next 10 years to support growing data demand for mobile use (FCC, 2010a). The FCC conducted a study after the release of the National Broadband Plan and projected that with growing mobile data demand, a spectrum deficit of nearly 275 MHz will be created by 2014 if more frequencies are not allocated for cellular use. This study is employed as the foundation for our research. Figure 1 shows forecasting data from the FCC of available spectrum for cellular use and mobile data demand growth from Cisco for the five year period starting with year 2009 (Cisco, 2011; FCC, 2010c). Cellular operators in the U.S. claim that America’s future competitiveness and technology leadership significantly depend on the nationwide availability of broadband and that, in fact, depends on the availability of additional spectrum (CTIA, 2011). With that assertion, cellular operators have been requesting that the FCC release more spectrum for mobile communication use. Finding this additional spectrum is a massive challenge since radio spectrum is an encumbered and finite resource. Therefore, the case regarding the magnitude of the spectrum scarcity related to the spectrum utilization should be studied.

The study presented in this paper employs a system dynamics approach to model and analyze the spectrum allocation and data demand situation. We utilize a stock-and-flow model...
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