"Frugal" 5G: Next Generation Wireless Systems for Connecting the Unconnected

Abhay Karandikar
Department of Electrical Engineering
Indian Institute of Technology Bombay
Mumbai 400076
India

In the recent years, there has been a significant growth of cellular wireless communications. Despite this growth, a large part of the world is still deprived of broadband connectivity. For example, in India, while the number of cellular subscribers is 1 Billion, the broadband penetration is mere 150 million. Moreover, the broadband penetration in rural areas is even marginal. It is estimated that 3-4 Billion population of the world still do not have access to Internet. Using existing cellular wireless systems including Third Generation (3G) and Fourth Generation (4G) technology, there are significant challenges in providing broadband access. These include - High capital and operations expenditure with low Average Revenue Per User (ARPU), lack of affordable backhaul, energy cost which is worsened by lack of reliable power supply and geographic accessibility including issues such as right of way.

These challenges require a re-thinking on developing next generation wireless system for connecting the unconnected world. Mobility is not a major driver for designing such systems, rather fixed primary broadband access is the most important requirement. A simplified IP based network architecture with dynamic spectrum sharing and a low cost wireless backhaul can set the vision of what we call "Frugal" 5G for connecting the unconnected.

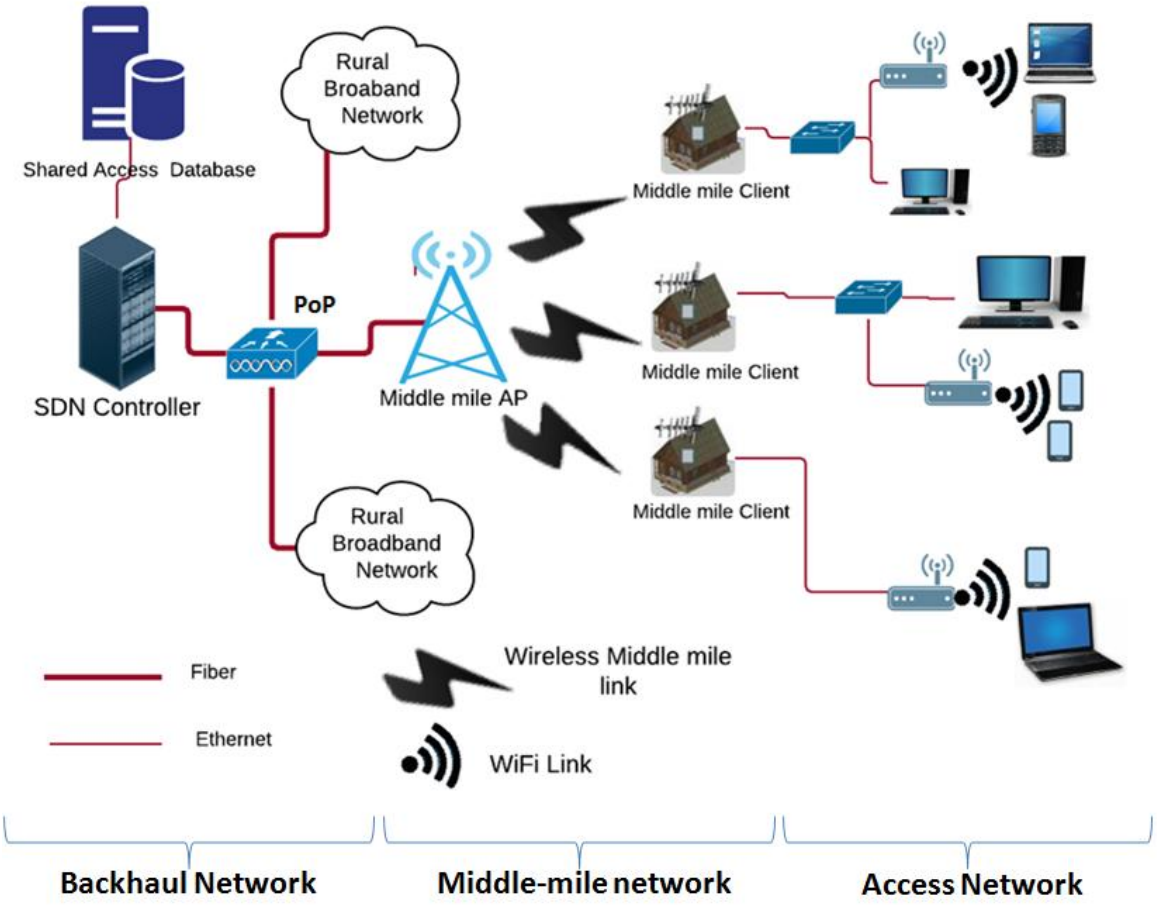
While affordable fixed access can be provided using a dense deployment of IEEE 802.11 based WiFi Hotspots, one of the major impediments for widespread deployment of such Hotspots is the lack of connectivity to WiFi access points. Fiber connectivity in terms of backhaul is limited in such countries and may currently reach only at designated points in a town or city. In such a scenario, the problem of connecting the core network to the access network can be addressed using wireless middle-mile network. Such a middle-mile backhaul can be provided using various solutions. One such solution could be based on TV UHF spectrum which is largely unutilized in many developing countries. Moreover, in order to reach these distances, sub-GHz spectrum provides excellent propagation characteristics, and at the same time will not require expensive infrastructure such as high towers and strict line-of-sight. Alternate solutions can be based on mesh network in mmWave.

This paradigm opens up several directions for technology solutions. These include dynamic spectrum sharing for multi-operator co-existence, scalable control and management of such access and middle mile network through software defined network controller among others.

Frugal 5G envisioned architecture

In order to suit these requirements, we envision the network architecture as shown in the figure below.

Envisioned architecture:



In most of the developing countries, the optical fiber generally terminates at the designated points near the rural areas. This fiber point of presence (PoP) can be extended to the villages in rural areas with the help of TV UHF band thus forming a *middle mile* network. TV UHF is largely unutilized in many developing countries and there is free spectrum available, called the TV white space (TVWS). This sub-GHz spectrum provides excellent propagation characteristics, non line-of-sight propagation and less expensive infrastructure such as low tower heights. The middle mile Access Point (AP) is deployed at the PoP and the middle mile client is deployed at the villages. These middle mile clients will further connect to the WiFi Access Points (APs). The end users in the villages can access the Internet via WiFi APs. Several such middle mile networks will be deployed in the rural areas and we need a solution to manage these middle mile networks. Software Defined Network (SDN) is one of the solutions for managing the network as illustrated in the figure above.

The connectivity requirements of the rural areas are very different from that of the urban areas. Thus in order to make rural broadband connectivity better feasible and have better penetration in the un-served and under-served remote and rural areas, we need low cost, indigenous and high performance solutions. The Frugal 5G approach is an economical and cost effective way of connecting the remote, un-served rural areas of India in an efficient and standardised way enabling greater innovation.