GREEN TELECOM LAYERED FRAMEWORK FOR CALCULATING CARBON FOOTPRINT OF TELECOM NETWORK

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Abstract

This paper presents the concept of green telecommunication network, and provides information about the carbon footprint within the fixed-line and wireless communication network. A section is devoted to describe the method with an example to calculate the carbon footprint of telecom network using Green Telecom Layered Framework. This framework aids in bridging the chasm between managing and mitigating the concentration of Green House Gases (GHG). The aim is to introduce the reader to the present green telecommunication, and outline the necessity of energy efficiency in Information and Communication Technology (ICT). This paper provides a comprehensive reference for growing base of researchers who will work on the energy efficiency of telecom network in near future.

Index Terms: *Green Telecom, Carbon Footprint, Layered Framework, and Green Network*

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1. INTRODUCTION

Of late, the rise in the world's surface temperature has become a matter of global concern, and is now comprehended as one of the vital challenges confronting humanity. Deteriorating natural resources, environment and climate changes have become an important concern to the world [1]. With advancing technologies, the world's need for the energy based solution increases, and due to the non-availability of efficient alternatives to fossil fuel energy sources, global temperature has risen and is expected to rise from 1.4˚C to 5.8˚C, with a doubling of CO2 concentrations over next 40 to 100 years [2].

With far and wide acceptance of ICT in each and every aspect of our society, it is believed to have an Eco-Friendly or Green image. This stature emanates from the fact that the modern telecom is transforming our society by providing travel and transport substitution. For instance: video conferencing, teleconferencing etc., on-line delivery, and other channels of reducing the human impacts on the environment. Virtual meeting that includes audio and video conferencing in lieu of travel could reduce CO2 emission by around 24 million tonnes per year [3].

ICT usage has grown at an almost exponential rate worldwide [4]. By 2015, the down-link traffic from cellular handsets is expected to grow more than eight folds, rising from 56 Megabytes per month to 455 Megabytes per month [6]. By the year 2020, nearly 80 % are projected to own mobile phone, and one in 20 households to have broadband connections [5].

In recent years, the ever-increasing demands for telecommunication services, has not only grown the energy consumption significantly and poses an environmental challenge in terms of larger carbon emission footprint of the telecommunication industry, but also presses telecom operators and vendors to spend less on energy and extract more efficiency out of their systems. Consequently, telecom vendors will need to take subtle decision of investing millions in new energy optimization technologies and offering enough innovations to satisfy not only their customers, but also their own bottom line [8].

From the global outlook, compared with coal, iron and steel, non-ferrous metal industries, the telecommunication industry is not the most prominent industry of energy consumption [1]. Albeit telecom is comparatively energy lean, the telecom networks are still driven largely by fossil fuel energy; therefore, the energy cost represents a significant Operating Expenditure (OPEX) item. In some telecommunication markets, energy costs account for as much as half of a mobile operator operating expenses [9].

As of now, in telecommunication industry, technological developments were acted predominantly on meeting Quality of Service (QoS) and capacity demands of the customer. Every year around 12,000 new base stations are deployed serving approximately 400 million new mobile subscribers around the world [7]. This growing infrastructure requires an increasing amount of electricity to power it, which increases the energy consumption base of the telecom industry. Hence, energy consumption of telecom network calls into questions, and it is indispensable to develop energy-efficient telecom solution.

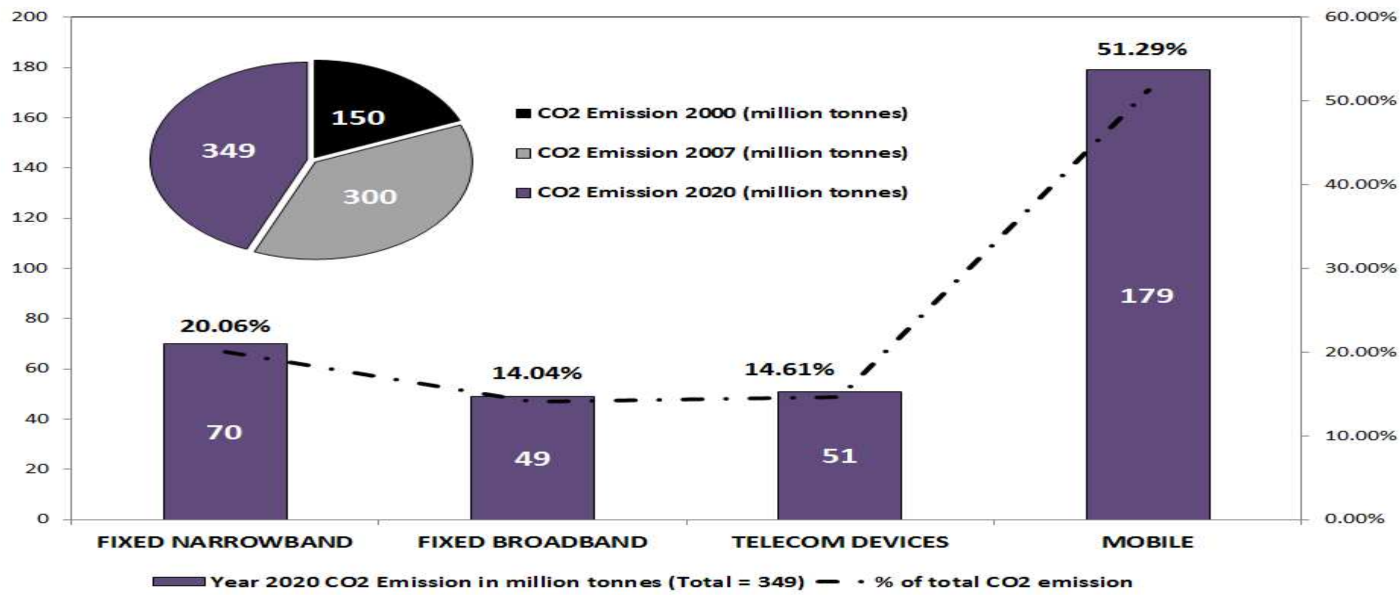

Fig. 1 Represents carbon footprint of ICT (in million tonnes) from the year 2000 to year 2020, and expected carbon emission from the different components of ICT for the year 2020 (in million tonnes)

The rest of the paper is organized as follows. Section II outlines the carbon emission footprint and energy consumption trend in ICT. Section III provides the detailed description of Green Telecom Layered Framework for finding the carbon footprint of telecom network. Last section concludes the paper outlining the possible future research topics.

2. CARBON EMISSION AND ENERGY CONSUMPTION OF ICT

With emerging new applications and technologies, ICT can enact both positive and negative roles. Thus, the relationship between ICT and the environment is complex and multifaceted [10]. The time, space, material, and energy needed to provide ICT services have decreased by three orders of magnitude since the first PC was sold [11]. However, to cater the meteoric growth in voice and data communication usage, large volume of telecom equipment will continue to be deployed both in the access network and the core network.

It is believed that continued improvements in energy efficiency technologies will reduce the energy consumption and provide a competitive advantage [12]. But due to increase in the stock of ICT appliances and network infrastructure to provide the uninterrupted services 24*7, the carbon emission footprint of telecom sector has risen significantly and will rise despite the development of energy-efficient technologies [13].

It is estimated that ICT sector worldwide is responsible for around 1% of the global CO2 emission [14]. The growth in the global telecommunication carbon emission has risen from 150 million tonnes of CO2 equivalents in 2002 to 300 million tonnes of CO2 equivalents in 2007, and is expected to reach 349 million tonnes of CO2 equivalents by 2020 [15] as shown in Fig. 1. This comprises the impact of personal computers, servers, cooling equipment, fixed and mobile telephone equipment, network infrastructure, LAN, and office communications etc.

The aforementioned components of ICT and their contribution of carbon footprint in ICT sector are shown in Fig 2. By 2020, ICT is expected to account for around 2% of the global carbon emission. According to the recent trends in up-and-coming applications and technologies, the number of fixed-line, narrowband, and voice telephony accounts is expected to remain fairly constant overall, but the number of broadband as well as mobile accounts is expected to grow more than double during this period [15].

The foremost share of the CO2 emission in the ICT infrastructure is during the actual use of the network equipment and devices. In the telecommunication network, the components that contribute to carbon emission footprint includes the Radio Access Network (RAN), fixed-line network, the Core network, aggregator, transmission system, and Fiber to the network (mainly in Access network) etc.

The distribution of power consumption across the network components is shown in Fig. 3. Among the components of mobile network, the Base Transceiver System (BTS) alone consume around 59% of the power in the network, while the Mobile Switching Center (MSC) constitute around 21% and the core transmission around 18% [15].

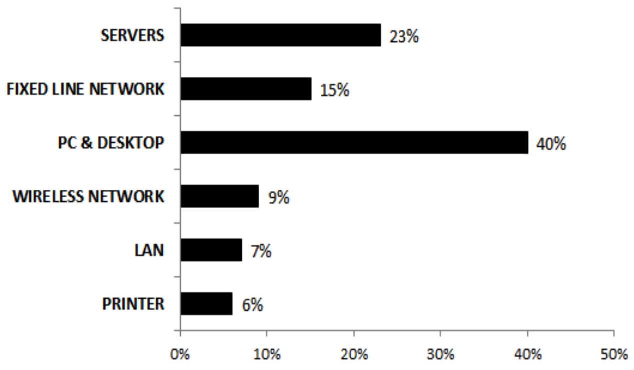

Fig.2 Contribution of different components of ICT to the carbon emission

Among the network components, in RAN: BTS alone consumes around 59% of power, and in Core: around 21% of power is consumed by MSC and around 18% by core transmission.

The predominant reason for the increase in the carbon footprint of the telecom infrastructure would be due to increase in the number of BTS, Base Station Controller (BSC), and MSC. The growth is not only due to the increase in the telecom infrastructure or number of broadband and mobile accounts, but also because of emerging new applications like sharing of videos, gaming, and other peer to peer content exchange [5]. Emerging markets offer vast growth potential for the telecom industry. A large global mobile market means more people connecting with each other, more base stations for vendor to deploy and maintain [10].

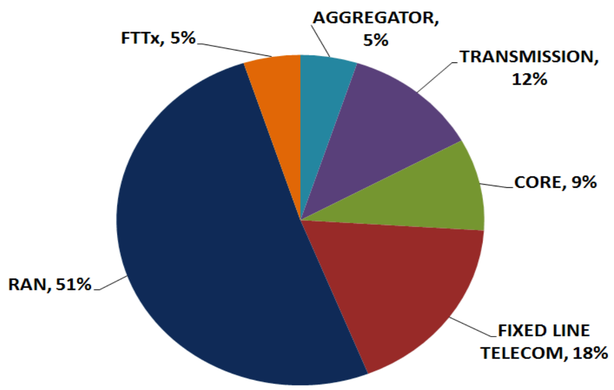

Fig.3 Distribution of power consumption across different components of telecommunication network

3. MEHOD TO CALCULATE CARBON FOOTPRINT OF TELECOMMUNICATION NETWORK

Green telecommunication is much discussed topic in the telecom industry and beyond. But still there are not enough definitions available that have made it difficult to gauge the effectiveness or the extent of its implementation. Every now and then, optimizing energy consumption in one part of a network can increase the power consumption and degrade the performance in another part of the network [16].

Managing a network effectively and operating it in a green manner is a complex task to perform. Therefore, the telecom industry has realized that the next phase of its growth is dependent on innovation in green technologies, and they have also recognized that, there is a very close proximity between energy saving and money. The combination of rising energy costs and our avid inclination for connectivity and data will lead to significant environment impact unless addressed by a unified strategy [17]. This is inspiring the network operators and business entities to pay more attention to their energy consumption and finally works towards its reduction.

3.1 Green Telecom Layered Framework

A Green Telecom Layered Framework takes a holistic view of telecom network architecture. It is divided into three levels: Network Component, Transmission Technology, and Network Equipment as shown in Fig. 4.

The first level is the Network Component. It can be broadly divided into two network domains: Core Network and Access Network.

A Core Network is the central part of the telecommunication network that provides various services to customers and end users. The core network generally refers to the backbone infrastructure of the telecom network which interconnects larger cities, and spans nationwide, and even intercontinental distances [18]. The core network is typically based on a mesh topology and carries huge amount of traffic.

An Access Network is the part of a telecom network which connects subscribers to their immediate service providers and to the core network. The access network is the “Last Mile” of a telecom network connecting the telecom Central Office (CO) with the end users [18]. It comprises the major part of the telecommunication network. It is also a major consumer of energy due to the presence of a huge number of active elements [19].

The second level is the Transmission Technology. The transmission technologies in core as well as access network are widely used to support the basic physical infrastructure. It is deployed for achieving high speed, high capacity, and scalability etc. [18]. For instance: Synchronous Optical Network (SONET)/ Synchronous Digital Hierarchy (SDH), Wavelength Division Multiplexing (WDM), Time Division Multiplexing (TDM) or Asynchronous Transmission Mode (ATM) etc. The aforementioned transmission technologies have been deployed over the past two decades [21].

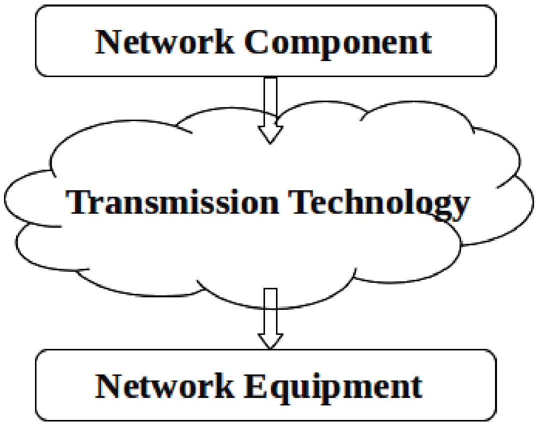

Fig.4 Green Telecom Layered Framework: three layer architecture namely Network Component, Transmission Technology and Network Equipment

The final level of Green Telecom Layered Framework is defined by the term Network Equipment. The network equipment level i.e. the telecom infrastructure level, consists of both hardware and software elements, and it is the main level at which the energy consumption of telecommunication network is investigated.

Consider an IP over WDM as an example as shown in Fig. 5. The WDM is the transport technology which multiplexes optical carrier signals onto single optical cable. A WDM transport system uses a multiplexer at the transmitter end for combining several optical carrier signals on one channel and de-multiplexer at the receiver end for separating them apart. The preamplifier and the power booster are used for amplifying the power of the optical signals so as to increase the sensitivity of the receiver and to compensate the power loss respectively.

Energy consumption of WDM transport network components can be found in switching level and also in transmission level. In switching level, the principal components that consume energy are Digital Cross Connect (DXC), routers or switches, and Optical Cross Connect (OXC). In transmission level, the components which are the main consumer of energy consist of multiplexer, de-multiplexer, transponder, pre-amplifier, and power boosters [18].

3.2 Carbon Footprint Calculation for Telecommunication Network

The measurement is the only step that bridges the chasm between manage and mitigation. But the problem with this first step is that, in many cases proper method to calculate the carbon emission from telecom network does not exists.
Even if organizations are unable to directly measure their telecom carbon emission and power consumption, they are often aware that it is too high and should be lowered if possible [22]. Therefore, choosing the right methodology to measure the carbon footprint of the telecom network is critical in ensuring that green telecom projects are successful over time.

The carbon footprint of the network equipment, that is, the telecom infrastructure is calculated based on the energy consumption at both, the network component layer and the transmission technology layer. The carbon footprint calculation can be divided into two parts depending upon the operation of the telecom network equipment: using Grid Power and using Diesel Generator (DG) Set.

3.2.1 Using Grid Power

PTE is the total power consumption of the network element including the power required for fan and other cooling equipment etc. (in kilowatt). PCO is the power needed for compensating the heat produced during the actual operation of the network equipment (in kilowatt) and PNE is the operating power of the network equipment (in kilowatt) given by the formula [23].

$$P_{TE} = P_{NE} + P_{CO}$$

$$P_{NE} = (0.35 * P_{MAX}) + (0.40 * P_{AVG}) + (0.25 * P_{SLEEP}), \quad [23]$$

Where PMAX is the maximum power of the equipment (in kilowatt), PAVG is its average operating power (in kilowatt) and PSLEEP is its power rating when operating in sleep mode (in kilowatt). The operation of the ICT equipment is at room temperature (via forced cooling).

The carbon emission EG (in tonnes per year) during the operation of network element using the power generated from the grid is given by

$$E_G = 0.365 * P_{TE} * E_{CO2} * H_G, \quad (1)$$

Where ECO2 is the carbon emission factor (in kilogram per kilowatt hour) and HG is the average number of hour's network element is operated using grid power per day.

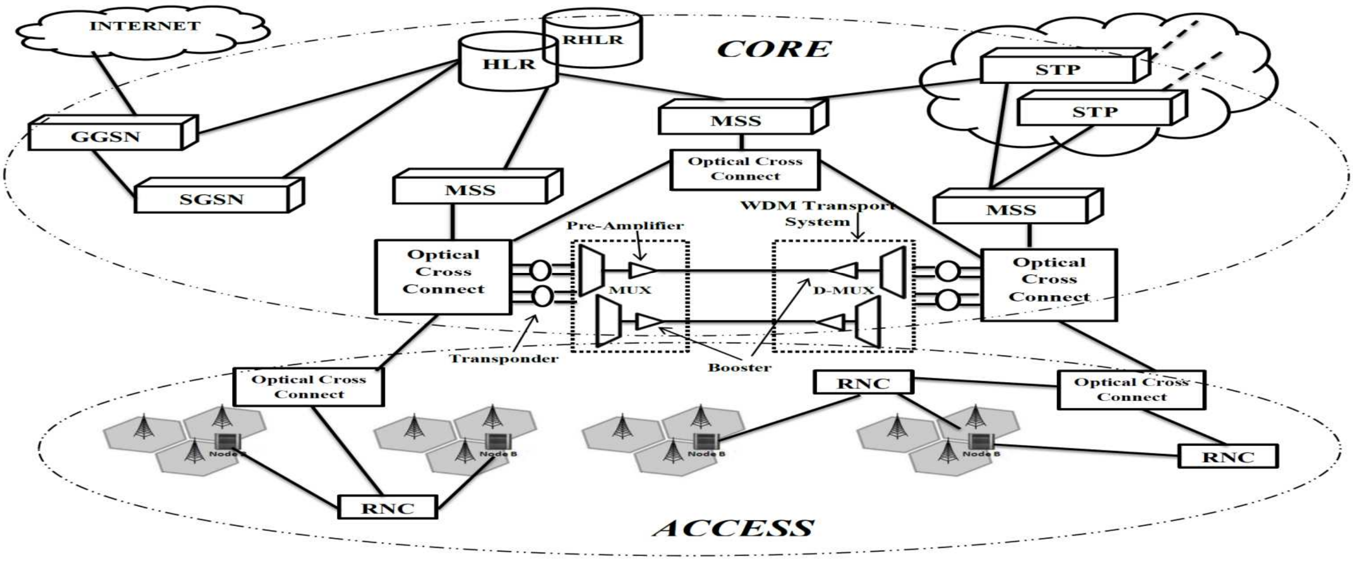

Fig. 5 Telecom network hierarchy

3.2.2 Using Diesel Generator Set

In remote regions, where grid power is available only for few hours in a day, vendors often rely on inefficient diesel generators, which will significantly grow the carbon footprint of telecommunication sector.

The energy density of diesel is 45.64 Megajoules per kilogram or 38.6 Megajoules per liter [24], which means 10.7 kilowatt hour of power is generated per liter of diesel. One liter of diesel produces 2.629 kilogram of CO2 [24], therefore, 0.2457 kilogram of CO2 is produced per kilowatt hour in one liter.

Let PDG be the capacity of DG set (in kilovolt ampere) having the power factor of $\emptyset$ used for HDG average numbers of hours network element is operated using DG set per day. The carbon emission EDG (in tonnes per year) during the operation of network element using the power generated from the DG sets is given by

$$E_{DG} = \frac{0.08968 * P_{DG} * \emptyset * N * H_{DG}}{\eta}, \quad (2)$$

Where N is amount of diesel (in liter) consumed by DG set in one hour and η is the efficiency of the DG set.

Carbon emission ET (in tonnes per year) of the telecommunication network equipment can be calculated by adding (1) and (2),

$$E_T = E_G + E_{DG}$$

Table 1 & 2 represent carbon emission calculation for core network in rural and urban area using method described above.

Table-1 Carbon emission calculation for core network in rural area

<table>
<tr><td colspan="5">RURAL</td></tr>
<tr><td colspan="4">Carbon Emission Calculation (GRID Power)</td><td rowspan="5">Total Carbon Emission (in tonnes)</td></tr>
<tr><td>Avg. Power Consumption of Network Element (KW)</td><td>Avg. Grid Power Supply (hours)</td><td>Carbon Emission Factor (Kg/KWH)</td><td>Emission (in tonnes)</td></tr>
<tr><td>1.76</td><td>13</td><td>0.523</td><td>4.3677</td></tr>
<tr><td colspan="4">Carbon Emission Calculation (DG Set Power)</td></tr>
<tr><td>DG Set Capacity (KVA)</td><td>Avg. DG Set Power Supply (hours)</td><td>Liters of Diesel Consumed (per hour)</td><td>Emission (in tonnes)</td></tr>
<tr><td>15</td><td>11</td><td>2.5</td><td>29.634</td><td>34.0017</td></tr>
</table>

Table-2 Carbon emission calculation for core network in urban area

URBAN				
Carbon Emission Calculation (GRID Power)				Total Carbon Emission (in tonnes)
Avg. Power Consumption of Network Element (KW)	Avg. Grid Power Supply (hours)	Carbon Emission Factor (Kg/KWH)	Emission (in tonnes)	
3.125	21	0.84	20.12	
Carbon Emission Calculation (DG Set Power)				
DG Set Capacity (KVA)	Avg. DG Set Power Supply (hours)	Liters of Diesel Consumed (per hour)	Emission (in tonnes)	
15	3	2.5	8.082	28.202

CONCLUSIONS

The contemporary scenario is exceedingly demanding and challenging, and the world's increasing need for the computation, data storage, and communication is maneuvering the rapid growth in the telecommunication, and intensifying the emission associated with enhancing technologies.

As mobile operators and vendors are making every effort to extend their network beyond the reach of power grids, they need to find the alternatives to non-renewable energy sources such as diesel, which is widely used today to power the telecommunication network. However, due to lack of enough definitions it seems to be difficult for translating this progress into the progress of sustainable development.

The Green Telecom Layered Framework gives insight into different layers of telecom network for calculating the carbon footprint emission depending upon the energy consumption at the telecom infrastructure level. Measuring the carbon footprint effectively should be the first priority for business entities, which paves way for managing the network by reducing the amount of energy required for system to operate without compromising the capabilities. And then think about the alternative energy options to minimize the overall carbon footprint of the system.

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