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Network tower sharing and telecom infrastructure diffusion in Ghana - a Structure-Conduct-Performance approach

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Network tower sharing and telecom infrastructure diffusion in Ghana - a Structure-Conduct-Performance approach

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Paper for

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Alexander Osei-Owusu and Anders Henten

Abstract

The paper answers the following questions: Whether the infrastructure sharing policy in Ghana has been able to achieve its core objective of preventing network tower investment duplication in single locations? And, whether the pricing strategy employed by tower owners encourages sharing? The foundation of these issues is concerned with the structure of costs of providing sharing services, the nature of contracts or other conditions for commercialization, and the clash of different buyers (MNOs – Mobile Network Operators) of tower spaces. The implications of these market conditions and the conduct of the market players for the diffusion of telecom infrastructure and services to poorly covered areas constitute the primary focus of this research. For assessing the market structure, the behavior of market players, and the outcome of the sharing policy, a Structure-Conduct-Performance (SCP) framework is applied. A combination of qualitative and quantitative data is used including interviews with employees of the network companies, tower companies, internet service vendors and the regulatory agency (NCA) and information on 2000 out of 5750 co-location tower sites across the country.

1. Introduction

Extensive infrastructure is required to build telecommunication networks. One of the key infrastructure elements in mobile networks is network towers. They make up a substantial portion of capital investments for mobile telecommunications.

The infrastructure sharing policy in Ghana, backed by a single and simple rights of way paragraph (§21.1) in the Electronic Communications Act of 2008 of the country, is aimed at reducing roll-out costs of telecommunication infrastructure by

mobile operators while also reducing the overall visual impact of towers on the communities. The rights of way paragraph allows mobile operators access to already built network towers owned by tower companies or other mobile operators.

The infrastructure sharing policy has since its introduction in Ghana's telecommunication industry opened a new wave of business models, where mobile operators have shifted the ownership and management of network towers to third parties (tower companies). By the end of 2014, all four top network operators in Ghana had signed long lease or sale agreements with multinational tower companies (American Towers, Helios and Eaton). The agreements of leasing are non-exclusive arrangements, enabling rights of way to operators renting a space and co-locating radio equipment on the same tower.

The paper answers the question: How does the infrastructure sharing policy affect diffusion of telecom infrastructure and services to poorly covered areas? To help answering this question, the following sub-questions are asked: Has infrastructure sharing policy been able to achieve its core objective of preventing network tower investment duplication in single locations? And, does the pricing strategy employed by tower owners encourage sharing?

The foundation of these issues is concerned with the structure of costs for providing sharing services, the nature of contracts or other conditions for commercialization, and the clash of different buyers (MNOs) of towers spaces. The implications of these market conditions and the conduct of the market players for the diffusion of telecom infrastructure and services to poorly covered areas constitute the primary focus of this research. An important issue is whether tower companies and network operators are indeed independent of one another or whether there is collusion between tower owners and network operators.

This research builds its formative understanding and arguments from an industrial organization analysis viewpoint. For assessing the market structure, the behavior of market players, and the outcome of the sharing policy, a Structure-Conduct-Performance (SCP) framework is applied. The SCP framework is the foundation to industrial economic analysis (Laffont and Tirole, 1993). The SCP framework is used for examining the operation of the telecom infrastructure market, in particular the network tower market, by focusing on three aspects of the market – structure, conduct, and performance or outcome. Here importance is given to understanding how the structure, and the conduct of the different market players affect the outcome (or performance) of the telecom towards the diffusion of telecommunication infrastructure and services.

Telecom infrastructure sharing policies are pursued by most countries including developing countries. Many pieces of research on telecom infrastructure sharing and access rights have focused on the projected savings on investments for providers of services and the advantages of allowing independent tower companies to manage such infrastructure, while service providers (network operators) focus on doing what they do best – providing telecom services to the users (osei-owusu and Armah, 2014; Osei-Owusu, 2015). Co-location could prove to be Africa’s best bet to improve telecom access on a continent where the high cost of transaction in doing businesses are impeding the roll-out of telecom services (Osei-Owusu and Anders, 2017). There is, however, a lack of research relating to the performance of independent tower management companies and the diffusion of telecom infrastructure and services in light of infrastructure sharing policy and other existing market conditions. This paper contributes to filling this gap.

The research will not only help provide a broader knowledge on the structure and conduct of Ghana’s telecom industry and its contribution to the telecom sector development. It will also aid the decision making process and policy formulation by stakeholders on issues regarding rights of ways and shared network tower infrastructure.

The study has adopted an analytical approach comprising a combination of qualitative and quantitative data collection methods. Selection of ten (10) employees of the network companies, tower companies, internet service vendors and the regulatory agency (NCA) for interviews were all done purposively. Regarding the measurement of performance, information on 2000 out of 5750 co-location tower sites (at the beginning of 2016) across the country has been collected.

The structure of the paper is as follows: The next section briefly introduces the concept of infrastructure sharing. This is followed by a section on the conceptual framework used for this research. Furthermore, there is a market analysis based on the SCP framework, and finally a conclusion with policy implications.

2. Infrastructure sharing in Ghana

Two major types of infrastructure sharing have been identified in the telecommunication service industry. Passive telecom infrastructure sharing is the sharing of physical supporting telecom infrastructure like network towers or masts and space, whereas for an active infrastructure sharing, it does require sharing of interconnection or network layers between network operators (Shabanpour et al. 2014). The second type requiring operators to share elements such as radio access,

nodes and transmission, network roaming and core-network equipment is known as active infrastructure sharing (Shabanpour et al. 2014). Ghana's infrastructure sharing policy advocates the former as a stepping stone for comprehensive infrastructure sharing in the future. For that reason, passive infrastructure sharing (specifically tower sharing) is selected as the case for this research.

Co-location is when antennas or transmitters of more than one network operator are located on a single tower. The term infrastructure sharing and co-location are most often used interchangeably. Once an operator shares the same space with another operator (operators placing their equipment side by side on a single tower) we say that they are co-locating or sharing the single network tower space. The principal benefit of infrastructure sharing is that there is no cost barrier since initial cost of erecting a tower is shared among multiple operators. Co-location also reduces the physical impact of towers in a location or community. Co-location, will result in building tall towers that can provide space for all different transmission devices (Shabanpour et al. 2014; Osei-Owusu and Armah, 2014).

3. Conceptual framework

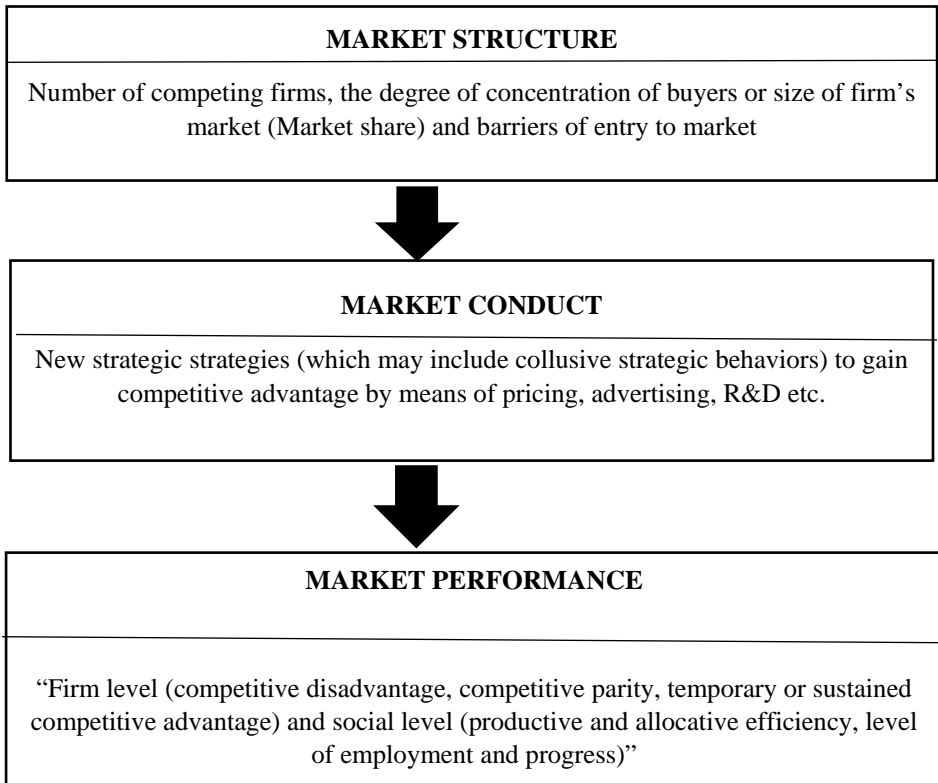
Understanding the behaviors of market players and how such behaviors impact on market performance is core to industrial organization economics analysis (Clarke, 1990). Beginning researchers into industrial organization (IO) economics (also known as the traditional IO economics) have presented a one way approach to the analysis, presenting a simple relationship between the market structure and conduct or performance of an organization (refer to Fu, 2003). This one way relationship analysis was epitomized by Mason in 1939, the original propendus, thereafter continued by Bain (1959).

Latest researches into IO economics industrial organization have presented IO economic analysis from the two-way traffic (Laffont and Tirole, 1993). Researchers from this paradigm has sought to include the reverse function of the one way approach by the traditional approach (Laffont and Tirole, 1993). The approach analyses how the conduct of the market players also affect the market structure.

The common framework performing IO economics analysis of firms or industries market is the Structure Conduct Performance (SCP) framework (Fu, 2003; Laffont and Tirole, 1993; Rainelli, 1996). The name structure-conduct-performance (SCP) framework indicates the elements of the market to be examined—the structure, conduct and outcome (performance) (Gilbert, 1984; Fu, 2003).

By dwelling on the SCP framework developed by Bain in 1959, this research support the assumption by Gilbert, (1984) “that the market structure will affect the performances of the firm or industry”. Figure 1 shows the simplistic one-way relationship among the three elements of Bain’s SCP framework

Figure 1: Bain’s SCP industrial market analysis framework



Source: Bain (1959)

Bain’s SCP framework

Bain version of the SCP is chosen over that of Mason in this research because Bain modification of the initial version of Mason introduced some fundamental exogenous factors which are very useful to the today's IO market analyses (Bain 1959; Rainelli, 1996). As suggested by Bain (1959), the included exogenous parameters were economies of scale, the function of production and demand, and the

impact of R&D. from the initial conception of the SCP framework, the implications of supply-demand, and innovations as a result of R&D investments.

The structure of the market

Under the market structure Bain described three important areas; the number of competing firms; the degree of concentration of buyers or simply the size of the firm's in question market and entry barriers to the market. The number of competing firms, and degree of market concentration are useful metrics in comparing a firm's position across the markets in question.

It appears that that the concept of a barrier to entry has now become the cornerstone of all industrial market analyses (Rainelli, 1996). "The existence of barriers to entry is assumed to be beneficial for incumbent firms" (Bain, 1959). "Incumbent firms can discourage new entrants by raising price above marginal cost" (Bain, 1959; Gilbert, 1984; and Fu, 2003). Depending on the size of their production units, some incumbent firm may sort to growing productivity to discourage new entrants (Fu, 2003).

The market Conduct

Bain presented a string of challenges that may result from market entry barriers. In Bain's view barriers to market may favor of large firms which in some cases leads to windfall profit (Bain, 1959; Fu, 2003). The string implications are that, large sums of profit may redefine firms conduct or behavior in the market and this is expected to impact on their performance (O'Sullivan and Sheffrin, 2003; Fu, 2003). Fear of barrier to entry was reechoed by Rainelli (1996), Rainelli posited that if firms are left unchecked and make entry so difficult to new entrants, they are soon becomes so powerful and possible collusive behavior may suffice (Rainelli, 1996). Collusion behavior, as noted by Rainelli in (1996) is an important type of conduct that limits competition. Collusion denotes a secret agreement or cooperation between different parties for deceitful purposes. "Collusion is an agreement, whether formal (like cartels) or informal (tacit collusion like price leadership) between parties to cooperate to limit competition and raise prices, increase market power and raise profits" (O'Sullivan and Sheffrin, 2003).

"Collusive behavior is a common feature of many oligopolistic markets where the decision of a few firm to collude may affect the entire market development" (Gilbert, 1984; Fu, 2003). The telecommunication industry is a typical case of an oligopolistic market. Majority of cases often dealt with in the economics literature are horizontal, where companies operate in the same markets (O'Sullivan and Sheffrin, 2003). However, collusion can also be vertical, in the sense that companies

constituting a supply chain cooperate in order to dominate the market (O'Sullivan and Sheffrin, 2003). In this paper, it is the vertical type of collusion which is analyzed. Specifically the relationship between tower companies and the network operators constitute a supply chain cooperation or collusion.

Performance of the Market

Bain presents two forms of measuring performance in the market (Fu, 2003). The first which is at the Firms' level, measures the combined impact of market structure and conducts on prices, cost and volumes of the products (Bressler and King, 1970). The tools for such performance measurement includes competitive disadvantage, competitive parity, temporary or sustained competitive advantage (Fu, 2003). The second form is at the social level, here performance is measured in relation to productive and allocative efficiency and level of employment and progress. How well, the network operators in Ghana are able to efficiently distribute their infrastructure services especially to remote communities, sticking to infrastructure sharing rather than duplications is central in the analysis of the social level performance of this paper.

4. Ghana's telecom infrastructure market analysis

In this section, Bain's SCP framework is employed as a toolbox for analyzing Ghana's telecom infrastructure market performance. Bain's framework provides input guidelines for analyzing each level in the framework. However, the actual specificities depend on the particular market to be analyzed. For this research, the following specificities form the basis for each level of analysis

Inputs for analyzing the structure of the telecom infrastructure market (market structure) include the market size, the degree of concentration on both the supplier side of the telecom tower infrastructure providers (being the tower companies) and the users or the demand side (being the MNOs), and major entry and exit barriers to obtaining co-location licenses and services (co-location agreements)

In the case of conduct analysis, the study has been seeking responses through interviews with ten respondents including current and former employees of MNOs and tower companies as to the reasons for implementing certain strategies such as pricing of shared infrastructure and inputs in co-location service agreements. The purpose has been to enable the study to conclude on specific kinds of behavior and conduct that have possible effects on performance.

According to Bain’s SCP framework, firm-based performance analysis considers firms’ competitive disadvantage, competitive parity, and temporary or sustained competitive advantage. Social performance analysis looks at production, allocative efficiency of product, and level of employment or progress - all in relation to the public good. Bain believes that a good market performance analysis for any public utility industry, as is the case for the telecom industry, should reflect both the interest of the firms and the public. However, most public policy advisors have focused more on social performance. This study focuses on the social performance because the outcome of the research is to aid policy decision on infrastructure sharing and diffusion of telecommunication services to rural areas. In all, there are 2000 collocation sites sampled for the co-location trend analysis part selected randomly from all the three tower companies: American Tower Company (ATC), Helios Tower Ghana (HTG), and Eaton Towers.

4.1 Structure of the telecommunication infrastructure market

This section is arranged as follows: First, market share and the degree of concentration for both MNOs and tower companies are presented; this is followed by conditions for market entry and exit emanating from infrastructure sharing agreements.

4.1.1 Market share and degrees of concentration

A company's market share refers to “the percentage of a specified market it operates in” (The New Palgrave Dictionary of Economics, 2008). The relative market share “measures the company's market share compared to the percentage of the market it does not control” (The New Palgrave Dictionary of Economics, 2008). Market size and relative market share are useful metrics in comparing a firm’s or a brand’s relative position across different markets. It reflects the degree of market concentration. Relative market shares above 33 are generally considered as being strong (Mason, 1939; The New Palgrave Dictionary of Economics, 2008). Market concentration may be used as a measure of competition, theorized to be positively related to the rate of profit in the industry - see (Bain, 1968).

Table 1: Market share of MNOs in Ghana, end-2016

Network operator	No. of subscribers	Market share (%)	Relative market share
MTN	15,686,399	48.5	94
Vodafone (VODA)	7,090,757	21.9	28
Tigo (MILLICOM)	4,695,887	14.5	17

Airtel	4,080,988	12.6	16
Glo	718,461	2.2	2
Expresso	90,617	0.3	0.02

Source: Researchers' field data (2016)

From table 1, it can be seen that MTN is far away from the next three closest competitors, Vodafone, Tigo, and Airtel in terms of market size and power. The relative market share of MTN is at 94, which is very high. Glo-Mobile and Expresso are at the bottom. In Ghana, MTN has played the leading role in the introduction of major services such as 4G and mobile money into the market.

ATC Limited is the leading network tower infrastructure provider, controlling more than 60% of the total towers sited across every part of Ghana. Most of their present towers were sold to them by MTN. Eaton Tower and Helios Tower, being the other two tower infrastructure companies, bought their towers from Vodafone, and Airtel and Tigo, respectively. The tower market is extremely concentrated with just 3 tower companies and a relative market share of ATC of 155.

Table 2: Market share of tower companies in Ghana, end-2016

Tower company	Estimated number of active towers nationwide	Estimated market share (%)	Estimated relative market share
American Tower Company(ATC)	3500	60.9	155
Eaton Tower Company	1350	23.5	31
Helios Tower Ghana Managed Services Limited (HTG)	900	15.7	19

Source: Researchers field data (2016)

4.1.2 Major conditions of entry and exit in the infrastructure sharing market

Focus has been on conditions regarding co-location services and license agreements, deemed as barriers to entry into the infrastructure sharing market. Similar entry conditions were found to run through almost all the agreements irrespective of the tower company involved. The agreement documents reviewed included: Agreements mostly from Eaton with their customers (co-locators) and Helios with their customers. Common entry conditions include co-location terms, site, and co-locator's insurance. Terms of decommissioning and relocation of equipment are considered to be exit issues.

Co-location terms

From the agreements, the co-location terms states that “the co-locator commits that it shall co-locate on a minimum of three hundred (300) co-location sites within twelve (12) months of the signature date, in accordance with the terms of this agreement, having identified over two hundred and fifty (250) such potential co-location sites by the signature date”. (Signature date means the date of signature by both parties to this agreement or the date on which the last party signs same).

For small operators, for example Espresso and Glo-mobile, such a condition may seem very difficult to fulfil. Even for existing operators (with some sizeable market share) who intend to move into a new market, fulfilling this condition may involve terminating other co-location service contracts elsewhere (with other tower operators) only to meet the minimum requirement of ‘committing 300 co-locating sites’ - the cost of cancellation of previous contract and moving of equipment alone is discouraging enough.

Co-locator’s insurance

Every prospective tenant or co-locator is expected to put in place a specified amount of insurance: Under the insurance terms the agreement states the following: “During the term of co-location service agreement, the co-locator shall maintain in force with a reputable insurance company the following insurance policies covering the use of co-location sites: Public Liability Insurance Policy: limit US\$ 0.5 million per claim; Goods and Transit Insurance Policy: limit US\$ 4 million per claim; Property Assets General Insurance Policy: value insured US\$ 20.5 million; and Plant & Machinery Assets Insurance Policy: value insured US\$ 0.15 million, and shall, on tower operators’ request, produce both the insurance certificate giving details of cover and the receipt for the current year’s premium”.

The fundamental reason for infrastructure sharing is and has always been the huge roll-out costs. Initial costs have always delayed diffusion of telecommunication services especially for developing countries. To shoulder such a huge insurance cost alone as a new operator may delay entry especially for smaller operators.

Site decommissioning and relocation

Terms for exiting a particular location or tower site as captured under decommissioning and relocation of equipment states the following: “Where co-locator wishes to terminate its lease on an individual site, co-locator may exit that site and cease paying the fee to the said tower operator three (3) months after co-locator has informed the tower operator of its intent to exit such Site, if the Site was not constructed for co-locator under a Build-to-Suit Agreement. The maximum

number of sites which co-locator may exit per calendar year may not exceed two per cent (2%) of the average number of sites covered by the agreement in the previous twelve months”. *Otherwise*, “the maximum number of sites which co-locator may relocate per calendar year may not exceed three per cent (3%) of the average number of sites covered by the agreement in the previous twelve months”.

The restrictions to exit a site to probably a cheaper or better site at any point in time may block an MNO’s decision to co-locate or enter a new market. The fast pace of innovation and consumer preferences in the telecom industry today requires network operators to make frequent decisions and restrictions on exiting co-location agreements may limit efficient performance of operators.

4.2 Conduct of operators in the telecom tower infrastructure market

This section discusses the conduct or behavior of the two major tower infrastructure market operatives, MNOs and tower companies. Issues such as how particular pricing strategies emerged, motives behind agreements and arrangements are discussed.

4.2.1 Conduct Cases

Before the diversification project (the sales of towers to tower companies), the two leading MNOs in Ghana, MTN and Vodafone, were sharing their infrastructure through a ‘barter trading system’ and employed high fee charges at certain locations to keep off the rest of competitors. (*“This is easily understandable because the two big companies’ tower infrastructure combined covered almost every part of the country and didn’t need the other mobile operators’ support” - Rankson-employee from MTN regional NOC*).

MTN led the tower diversification project by selling the majority of their proprietary tower to ATC to provide independent management services, which was later to be replicated by the rest of the MNOs, Airtel, Vodafone and Tigo. Tower companies are now able to provide independent sharing services to many MNOs for commercial purposes applying a fixed price strategy. (*“The fixed price strategy was in part inherited from the way MTN and the other operators dealt with sharing among themselves” - Robert Nketia, former employee of MP-infrastructure, Ghana*).

ATC, the biggest tower company in Ghana later introduced a more specific approach to applying the fixed pricing strategy by charging differently for different tower locations, which was later to be replicated by all the other tower companies in Ghana. Three specifications based on location were introduced: platinum, gold and

silver. Criteria for naming platinum, gold and silver towers include: 1) whether towers at such site double as backhaul/hub or repeater station, 2) if the tower are sited at very high, high or less economically favorable environments, i.e. rural, peri-urban and urban locations. A site is said to be platinum if it is located at a center of a business hub or a location with very high economic activity. In special cases, some sites in less economic activity locations can still be in the platinum category if only it is a backhaul or a repeater station. For platinum sites, either one of these conditions must be fulfilled. Gold and silver category towers are located in a high and less economic activity zones or locations respectively. Highest extra charge is for platinum, followed by gold and silver. (*“Putting more cost to’ very high’ economic or commercial areas will only close down competition on the smaller telcos” - Ibrahim, M-P infrastructure*).

“The workers who used to manage the towers when they were owned by the operators are now working with the tower companies since the takeover from the mobile operators. Most of them hold management positions. The decision to keep the former workers at post was something agreed between the MNOs and the tower companies before the takeover. These former workers are just making co-location very difficult for other operators just to favor their former pay masters” - (from one interviewee from ATC). The possibility of MNOs colluding with their former employees who are now working with the tower companies to keep their interest intact is very high.

“It is unlikely for example for ATC to take major decisions without consulting MTN, especially when all the greater percentage of the revenues are coming from MTN” - (an employee from MTN, Capital Projects). Currently, after the emergence of the tower companies, the situation has not changed much. MTN and Vodafone still enjoy market dominance. Tower companies continue to target the top mobile operators to make their revenues. (*“Co-location license and service arrangements and contracts are not the same, for example for my company (MTN) and let’s say Airtel” - an employee from MTN*).

The nature of tower contracts signed during the tower sales among the top four mobile operators and the three tower companies has created some ‘superior position’ over the rest of the network operators. After all, the tower companies are not independent enough. (*“Having to document that (a co-locator) will co-locate a minimum of 300 co-locations before co-location license and service is granted, is a strategic idea emanating from the two market monopolies, MTN and Vodafone, just to keep their competitors at bay” - one interviewee from Eaton towers*). The question here is, supposing the tower company makes more profit from the number of co-locators, why keep such a huge condition to deter others off? (*“I think the condition of having to documents these numbers of co-locations before obtaining*

services has worked largely for the dominant MNOs such MTN, who has and may continue to monopolize most parts of peri-urban and all rural communities; visit most parts of the north and it is all about MTN or Vodafone” - Hansin, a former Ghana telecom worker).

“The ‘behind the scene manipulation’ by the big operators has become more muddled at some of the tower sites. Some it only affects us when there are power cuts; at a point when the generator is unable to power all the tenants, priority is given to some tenants; we prefer to build our own towers rather than share, even if this will take years” - Emmanuel is working with Globacom Ghana, GLO).

It is only fair to say that the conduct or behavior of the leading MNOs are not helping to promote infrastructure sharing policy and diffusion of telecommunication services. The above responses from respondents from the interviews reveal that there is market collusion by the leading MNOs, especially MTN and Vodafone, to wade of the other small competitors by hiding behind tower companies to manipulate the market.

4.3 Performance of Ghana’s telecom infrastructure sharing market

The performance analysis begins with the trend of co-location across the country with a satellite presentation of the current state of tower distribution across Ghana (looking at it from the north and south division). This is followed by a network coverage analysis, relating the extent of coverage of operators’ radio and the average trend of co-location in rural communities in order to measure the extent of diffusion of telecom services across Ghana. The 2G GSM-900MHz system is chosen as the case equipment since it is the most widely used radio equipment for voice telephone especially in the rural communities in Ghana.

4.3.1 Co-location analysis at various sites across Ghana

Table 3 presents a large sample of tower sites, 2000, across tower site classifications (platinum, gold and silver) from the three tower companies, American Tower Company (ATC), Eaton Towers and Helios Towers Ghana (HTG).

Table 3: Trend of co-location in Ghana

Tower Site	No. of	Number of Co-locators
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Category	Sites	1	2	3	4	5 ⁺
PLATINUM	630	240	35	85	102	168
GOLD	510	206	53	79	61	111
SILVER	860	645	215	-	-	-
TOTAL (%)						
	2000	1,091 (55%)	303 (15%)	164 (8%)	163 (8%)	279 (14%)

Source: Researchers field data (2017)

Platinum sites, mostly located in the cities (urban centers) have an average of three (3) co-locators per tower site. There were 630 sites identified as platinum out of the 2000 sites sampled. 240 (38.1%) of them had only one (1) co-locator; 35 (5.6%) had two (2) co-locators; 85 (13.5%) had three (3) co-locators, 102 (16.2%) had four (4) co-locators; and the remaining 168 (26.7%) had five or more co-locators.

Gold sites, mostly located at peri-urbans, also have an average of three (3) co-locators per a tower site. Out of 510 gold sites, 206 (40.4%) had only one co-locator; 53 (10.4%) had two (2) co-locators; 79 (15.5%) had three (3); 61 (12%) had four (4) co-locators; and the remaining 111 (21.8%) had more than five (5+) co-locators.

For silver towers, mostly located in rural communities, there is an average of one (1) co-locator per tower site. 645 (75%) out of the total 860 sampled sites had one (1) co-locator; the remaining 215 (25%) had no more than two (2) co-locators.

The analysis reveals interesting facts about co-location in Ghana. For platinum and gold locations where, due to economic value of locations, the general expectation is to have multiple co-locators dominating the tower sites, 38% and 40% of selected tower sites for platinum and gold respectively had only one co-locator.

Silver tower are yet to experience competition. 75% of them have just one co-locator. There are no other alternative to infrastructure sharing rather than to build individual towers.

From the overall analysis, clearly there is still more than 50% tower sites in Ghana with just one co-locator. The conclusion is that incumbent operators have been able to hold onto their dominance for large part of infrastructure location.

4.3.2 State of diffusion of network towers in Ghana

Figure 3 shows a satellite view of all documented tower locations in Ghana (there were 5750 towers locations in Ghana as at 2016). It also provides information on the specific tower, platinum, gold and silver. The study divides the country into two: north and south.

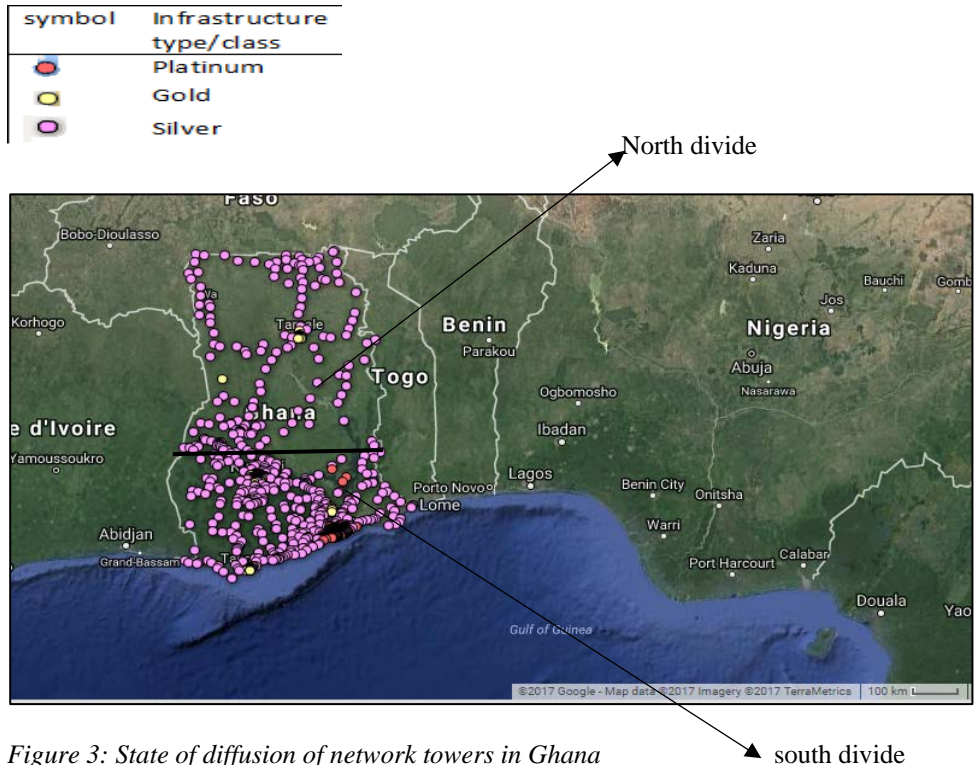


Figure 3: State of diffusion of network towers in Ghana

[There are 200 tower sites represented in figure 3. The size of the map means that the majority of the tower sites are not visible and they have been superimposed or hidden beneath one another]

Comparing the distribution between the north and south of Ghana shows a very big infrastructure gap. The only dominant tower class in the north is the silver category with few gold towers found at Tamale, one of the central cities in the north. There is a clear indication of uneven distribution and allocative inefficiencies. Close to the border of Ivory Coast, there are a larger number of towers located. The border towns serve as major market centers and transiting point for smuggled goods such as cocoa and agro-chemicals. Ghana and Ivory Coast have a long rivalry of becoming the number 1 leading producer and exporter of cocoa. Depending on how much the government pays for cocoa farmers per bag of cocoa, smuggling is intensified into or

out from one of the countries. Human traffic at these borders as a result of the commercial activities means these areas are viable point for mobile communication infrastructure and services investment.

Figures 4, 5 and 6 suggest double and multiple tower allocations at the same locations especially for most cities within the south divide.

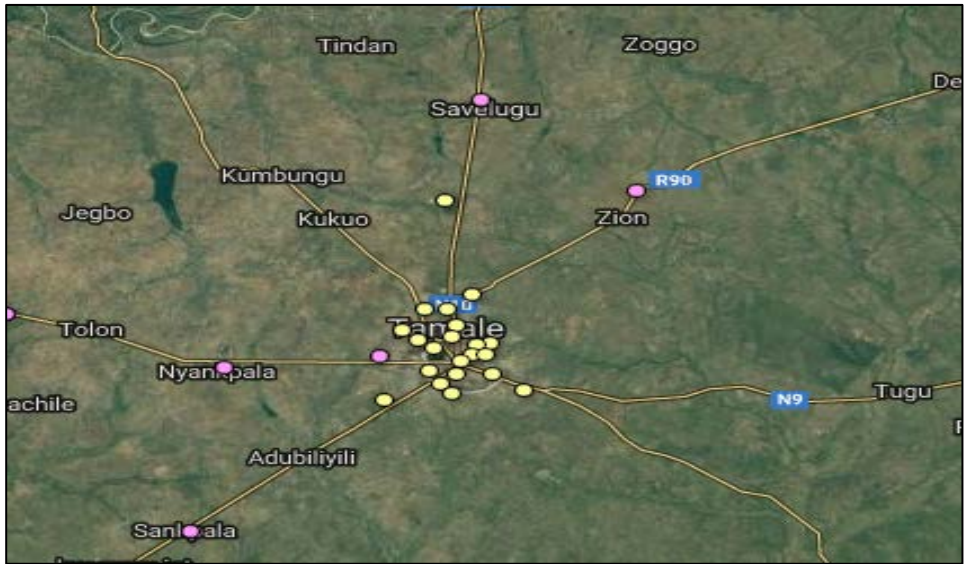


Figure 4: Sites located at Tamale

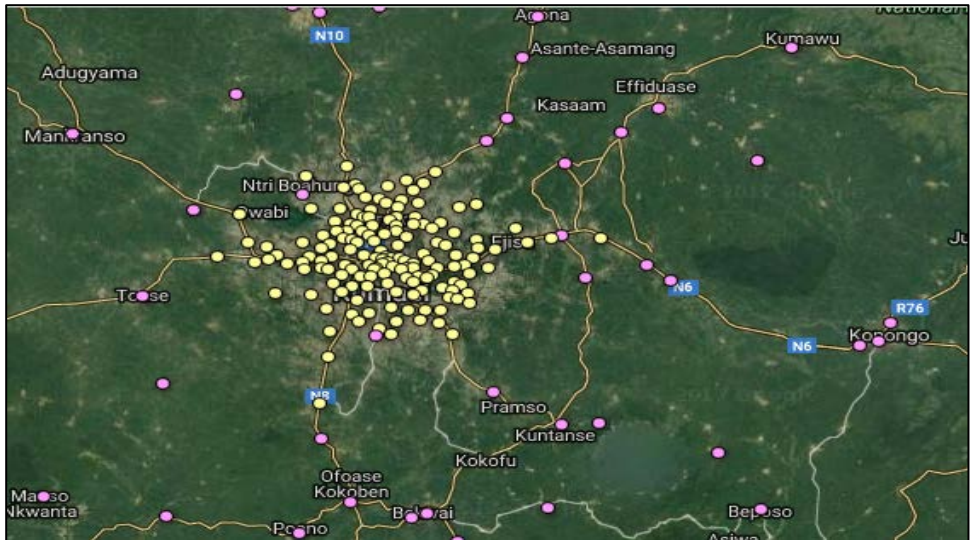


Figure 5: Tower investments at Kumasi

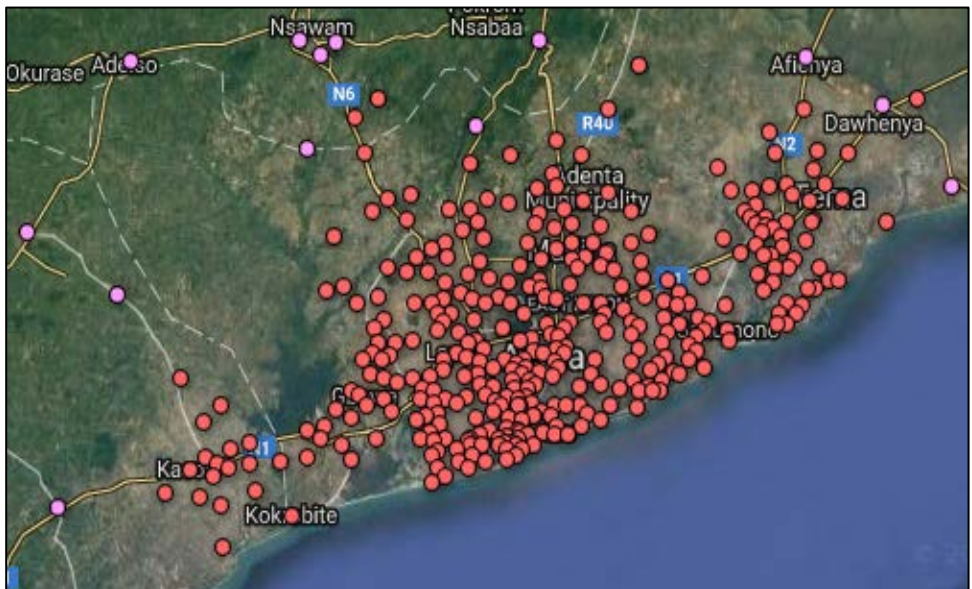


Figure 6: Tower investments in Accra

The principal benefit of infrastructure sharing is that fewer towers are needed to serve a given area. Double and multiple network towers at the same locations call into question the effectiveness of the infrastructure sharing policy. As can be seen in the case in figure 4, 5 and 6, for most of the large cities in Ghana, Tamale, Kumasi, Accra etc., there are a number of single investments cumulating into multiple and excess tower sites at single locations while other smaller towns badly need areas to be covered.

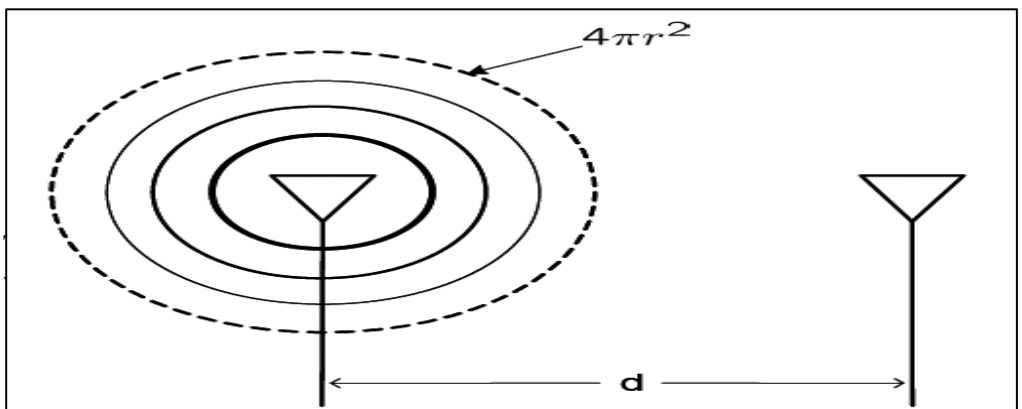
4.3.2 Network coverage analysis

GSM is the first true digital cellular system that was commercially implemented globally. The common radio equipment used by all the network operators in Ghana is a GSM system. Furthermore, UMTS is also applied among MNOs in Ghana, and currently MTN has deployed 4G-LTE in some cities, especially Accra. For most of the rural communities, the GSM system is the most predominant (especially in the rural communities). Therefore, the GSM system is chosen for the coverage analysis.

The GSM system in Ghana operates within the frequency band, 900 MHz band. Data from Tower data and coverage maps on Ghana from CellMapper.net. <Available at <https://www.cellmapper.net/>> [Accessed on Wed, 15 Mar 17 16:11:43] provides the following information on coverage for GSM systems in Ghana.

[GSM-900(band 900); ARFCN=96; Maximum signal (free space pathloss) =-65dBm; Uplink frequency= 909.2MHz; Downlink=954.2MHz]

The interest here is to find the distance (d) from the network tower site where the radio equipment of the operator is based to the last line where beyond it, a phone user (mobile station) cannot access communication signal unless a supporting tower site or a repeater station is nearby.



$(L_p)_{free} \rightarrow$ Which is the free space path loss (mostly used in line of sight radio propagations)

$$L_p = \left(\frac{4\pi d}{\lambda} \right)^2, \text{ often expressed as an attenuation in decibels (dB)}$$

$$= \frac{20 \log(4\pi d)}{\lambda} \text{ (dB)} \dots \dots \dots \text{eqn (1)}$$

In general, radio wave propagation consists of three main attributes: reflection, diffraction and scattering. During transmission, when transmission waves experience various attributes as a result of transmission through different mediums, meeting obstructions such as walls, building, mountains etc., part of the radio wave energy may be lost resulting in attenuated wave (expressed as free space pathloss (L_p))

From eqn (1) we can calculate for the maximum distance (d) at which a GSM system operating in Ghana can reach.

$$L_p = \frac{20 \log(4 * 3.142 * d)}{0.3}, \quad \lambda = c/f, \text{ where } c = \text{velocity of electromagnetic waves in the free space } (3 * 10^8 \text{ m/s}), f = 900 \text{ MHz}$$

d = antenna separation distance between transmitter and receiver (i.e., base station and mobile station)

$$65 = 20 \log 42 * d$$

$$d = 2 \text{ km}$$

Considering all factors, such as the geographical shape of Ghana and the calculated attenuations as a result, a GSM system operating at 900MHz band covers up to a distance of 2km

The absolute radio frequency channel number (ARFCN) that specifies a pair of physical radio carriers used for transmission and reception is 96. This means that the capacity of the system at any point in time can hold 96 calls for customers found within the 2km radius of the radio equipment (cell site). *[Note: The new improved 2G systems currently deployed in Ghana operating at 1800MHz band, has a coverage distance of 1.1km and available capacity of 602 channels].*

Given the analysis above and the fact provided from the co-location analysis at table 3, silver tower sites, predominantly located in rural communities, have an average of one (1) co-locator or network service provider. This implies that the single network

operator is able to provide service within the 2km radius, with a channel capacity of 96 at a time. Any community that stretches beyond 2km is not reached, and within the coverage limit of 2km, the GSM-900 system is able 96 of the subscribers at a time.

6. Conclusion

Against the expectations of the regulator, infrastructure sharing is currently not effective. In commercial and big cities such as Accra and Kumasi, where expectations were to more co-locations, surprisingly about 40% of tower sites have only one (1) co-locator.

The nature of the agreements and sales of towers have positioned the MNOs involved as anchor tenants, on commercial terms. This has created a great deal of market misconduct. Tower companies are not 'independent'. For instance, MTN provides more than half of the revenues for ATC and, therefore, most of the decisions taken, including co-location contracts for other competitors. Pricing of infrastructure is done to favor to maintain the MTN dominance. This has been confirmed through various reviews of co-location contracts and interviews granted.

Network operators in most of the regional capitals or cities have rather chosen to build their own individual towers, resulting in double and multiple tower investments at the same locations. For rural communities, rather than sharing amidst non-pleasant market conduct from the incumbent operators, new entrant operators have chosen to build their own towers, holding back diffusion due to single cost ownership. Building of different towers by new entrants or operators defeats the fundamental objective of infrastructure sharing.

The most dominating radio equipment in Ghana is GSM (operating at 900MHz) widely used in rural communities and surrounding towns. Villages of the regional capitals cannot provide network services beyond 2km and may hold capacity of 96 subscribers at a time, even for the improved GSM (operating at 1800MHz) only a capacity of 600 subscribers within the range of 1.1 km can be reached. Communities beyond coverage areas require more than one co-locator and network tower.

Factors such as market size of firms and their degree of concentration will continue to affect conduct and performance, unless there is a strong institutional incentive for undertaking mandatory access strategies to challenge dominance to induce greater competition in markets.

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