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MOBILITY 2019 Editors

Przemyslaw Pochec, University of New Brunswick, Canada

MOBILITY 2019

Forward

The Ninth International Conference on Mobile Services, Resources, and Users (MOBILITY 2019), held between July 28, 2019 and August 02, 2019 in Nice, France, continued a series of events dedicated to mobility-at-large, dealing with challenges raised by mobile services and applications considering user, device and service mobility.

Users increasingly rely on devices in different mobile scenarios and situations. "Everything is mobile", and mobility is now ubiquitous. Services are supported in mobile environments, through smart devices and enabling software. While there are well known mobile services, the extension to mobile communities and on-demand mobility requires appropriate mobile radios, middleware and interfacing. Mobility management becomes more complex, but is essential for every business. Mobile wireless communications, including vehicular technologies bring new requirements for ad hoc networking, topology control and interface standardization.

We welcomed academic, research, and industrial contributions, technical papers presenting research and practical results, position papers addressing the pros and cons of specific proposals.

We take here the opportunity to warmly thank all the members of the MOBILITY 2019 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to MOBILITY 2019. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

We also thank the members of the MOBILITY 2019 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that MOBILITY 2019 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the field of mobile services, resources and users. We also hope that Nice, France provided a pleasant environment during the conference and everyone saved some time to enjoy the charm of the city.

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On the Forward Path Detection Time Metric for Evaluation of Ad Hoc Routing Protocols

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Abstract—**When considering the performance of an ad hoc network, and the impact of routing protocols on it, one factor at play is the time required for setting up the forwarding path. This delay can make a significant impact on the estimate of the steady state throughput particularly when the data transmissions during the performance evaluation are short and the routing path changes often. In this short paper, we quantify the difference in the forward path detection time for two sample routing protocols: one proactive and the other reactive. Our results show significantly shorter path set up times for the Ad hoc On Demand Distance Vector (AODV) vs Destination Sequenced Distance Vector (DSDV) protocol.**

Keywords-Ad hoc routing; performance metrics; AODV; DSDV; MANET; M2ANET.

I. INTRODUCTION

Multiple factors impact the performance of ad hoc networks. Typical metrics used in comparison between different configurations include the packet delay and the packet delivery ratio [1]. Calculation of these (and other) performance metrics can be affected by the time preceding the actual transmission, which is needed to set up the routing. In our experiments with Mobile Ad hoc Networks (MANETs), we noted a significant difference in the network performance when switching from one routing protocol to another [2]. On a closer inspection, we noted that the actual data transmission (as opposed to the exchanges of control information between the nodes) did not start immediately in some experiments. This set up time, which we call the Forward Path Time Detection (FPTD) time, may have a significant impact on the interpretation of the results of the performance evaluation of an ad hoc network as the actual instantaneous throughput may be significantly different form the calculated average when a significant delay in setting up the routing is not taken into account.

In Section II, we review the three principal metrics used in network simulation and define one secondary metric explored in this paper. Section III is the description of the experiments where we observed the differences in path set up time (FPTD). The analysis of the results is in Section IV and the conclusion is in Section V.

II. STATE OF THE ART

A MANET is created from a group of mobile wireless nodes exchanging messages with one another [3]. Multi-hop transmissions are possible when routing is used to forward packets to more distant nodes. A deployment of a MANET is characterized by the physical parameters of transceivers at each node, the number of nodes used, their movement pattern and the routing and transmission protocols used. They all impact the performance of the network.

Given a MANET with its many complicated deployment characteristics, simulation can be applied to evaluate its performance. In network simulation, and for MANETs in particular, different performance metrics are used to evaluate the network operation [1]. The communication channel throughput, measured as data delivery rate from the source to the destination is the obvious principal metric. It depends on the physical characteristics of the wireless channel between the network nodes, and additionally on the network conditions, such as the location and the velocity of the nodes, that may vary significantly in a MANET due to the mobility of its nodes.

To account for all kinds of transmission impairments, the Packet Delivery Ratio (PDR) is commonly used. PDR is the ratio of the number of packets received by the destination to the number of the packets sent by the source (or generated by the source agent). PDR is affected by the changes (and disconnections) of the forwarding path due to the mobility of the MANET nodes.

End-to-End Delay, or packet delay, is the average transmission time for the data packet from when it is sent from the source until it reaches the destination. The delay time includes any delays caused by routing, buffering, queuing, retransmission, or propagation.

The FPTD time is the set up time between the request to send at the source node and the detection of the first forwarding path. Due to the highly dynamic nature of MANETs, some routing protocols take a longer time than other protocols to find the route and forward the packets from the source to the destination. This delay in finding the first forwarding path may affect other network performance measures, in particular the PDR.

III. EXPERIMENTS WITH M2ANETS

Experiments that led us to use the FPTD metric were concerned with the performance evaluation of the novel configuration of a MANET we called Mobile Medium Ad hoc Network (M2ANET). We introduced the concept of a

Mobile Medium in our seminal paper on M2ANETs in 2011 [4]. A M2ANET realizes the connection between two hosts with the cloud of nodes serving as the data communication medium (aka Mobile Medium) and forming the communication channel. Any particular connection in the Medium does not matter as long as the channel between communicating users of the M2ANET can be formed. As a consequence, M2ANETs exhibit fault-resilience, given that they are not operating with a single point of failure. The performance of M2ANETs was evaluated for different node densities [4][5], different movement patterns [6][7], with self-organizing nodes [2] and in the presence of competing flows [8]. Examples of other networks operating on a similar principle include the Google Loon project [9], Facebook's flying internet service [10] and a swarming micro air vehicle network (SMAVNET II) [11].

In our typical M2ANET simulation [2][4]-[8], the random mobility model was used as a reference case scenario, mostly because it is a standard model used in network simulation. The model used was the Random Way Point (RWP) model available in ns2 [12]. In RWP, nodes are moved in a piecewise linear fashion, with each linear segment pointing to a randomly selected destination and the node moving at a constant, but randomly selected speed. In our experiments, the mobile nodes forming the Mobile Medium moved at random speeds with an average speed of 4 m/s within a square area 1000 m by 1000 m. The main communicating nodes 0 and 1 were stationary. The source and destination nodes were located at (50,400) and (950,600) coordinates, respectively. The simulation details are summarized in Table 1.

TABLE I. SIMULATION PARAMETERS

Parameters	
Simulator	ns-2.34
Channel Type	Channel / Wireless Channel
Network Interface Type	Phy/WirelessPhy
Mac Type	Mac/802.11
Radio-Propagation Type	Propagation/Two-ray ground
Interface Queue Type	Queue/Drop Tail
Link Layer Type	LL
Antenna	Antenna/Omni Antenna
Maximum Packet in ifq	50
Area (n * n)	1000 x 1000m
Source node location	(50, 400)
Destination node location	(950, 600)
Source Type	CBR over UDP packetSize_ 512 interval_ 0.05
Simulation Time	500 s
Routing Protocol	AODV and DSDV

The data traffic for the data flow was modelled with the Constant Bit Rate (CBR) traffic generator and sent using User Datagram Protocol (UDP) over simulated Mobile Medium network with four different node densities from 10 to 40 nodes. Node density indicates the total number of mobile nodes in the 1000 m by 1000 m square region modelled in the experiments. Each mobile network scenario was simulated three times for a 500 second simulation run time and the average results was taken. While, in general, the network performance can be characterized using a variety of metrics, in this paper we focus solely on FPTD.

IV. RESULTS AND ANALYSIS

In our analysis here, we focus on the performance of two routing protocols: reactive AODV and proactive DSDV [13][14].

In an experiment with a network formed by very few nodes (10 nodes), AODV took an average 190 seconds out of 500 second simulation run time to detect the first forwarding path (Figure 1). However, when the number of nodes increased, the FPTD metric dropped significantly: for 20 nodes the delay to detect the forwarding path was down to 25 seconds. In a network with 40 nodes, the delay was only 1.2 seconds. Detecting the forwarding paths early increases the PDR and the network performance in general.

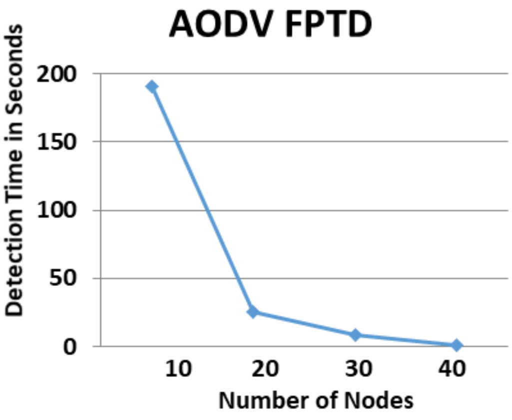

Figure 1. FPTD for AODV routing

In the experiments with a MANET running DSDV routing, due to the proactive nature of DSDV, detecting forwarding paths takes a longer time compared with the experiments over AODV (Figure 2).

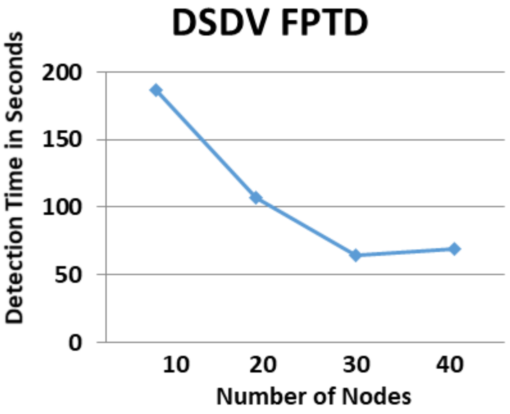

Figure 2. FPTD for DSDV routing.

DSDV displays a poor ability to detect the routes quickly in highly dynamic mobility networks and it takes more time advertising good routes and recovering broken ones. In a mobile network with only 10 mobile nodes, DSDV took an average of 187 seconds to detect the first forwarding path, which is at par with AODV. However, it took as much as 106 seconds to detect the first forwarding path in 20 mobile node density scenario compared with 25 seconds for AODV with the same node density. The FPTD for a network with 40 nodes is 69 seconds for DSDV, which is 50 times more than FPTD in AODV experiments. Longer FPTD times mean longer period of idling in a network before the first packet is sent and consequently less time spent actually transmitting data and lower PDR.

In the two series of experiments, the protocols exhibited very long FPTD delays and performed similarly when the number of nodes forming the network was very small (10 nodes). This is likely caused by a very sparse positioning of nodes over 1000x1000 m simulation area, with no forwarding path existing at all until the mobile nodes get into favorable positions making the source to destination connection feasible. At higher nodes densities (40 nodes) the feasibility of the path is almost certain, and the FPTD delay is primarily determined by the performance of the routing protocol, with AODV showing clear advantage.

V. CONCLUSION AND FUTURE WORK

Performance metrics that use averages calculated over the experiment simulation time can be skewed by the phenomena particular to some ad hoc routing protocols. While experimenting with M2ANETs, we observed significant differences in the path set up times between AODV and DSDV. In a reasonably dense ad hoc network, the DSDV set up times were at high multiples of AODV set up times: four times larger in a network with 20 nodes vs 50 times larger in a network with 40 nodes. This difference in set up times may need to be taken into consideration when comparing performance measures for the networks using different classes of protocols: reactive *vs* proactive.

In future, we plan to propose different types of performance metrics that would better reflect the steady state performance of ad hoc networks and that are unaffected by the differences in set up times.

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Spectrum Sharing Analysis; An Approach to Increase Mobile Systems Capacity.

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***Abstract*—In this paper the spectrum sharing has been analyzed as a viable alternative to increase the mobile systems capacity, in order to satisfy the growing demand for these services. In this paper, the television white spaces and the C band are analyzed as potential spectrum candidate to implement sharing spectrum schemes in México. Using their geographical localization, some cities along the Mexican territory are evaluated to determine viability and impact. The evaluation was done considering some International Telecommunication Union (ITU) recommendations, applying technical parameters to calculate coverage area protection and potential data rates.**

Keywords- Sharing spectrum; C band; TVWS.

I. INTRODUCTION.

Around the world, more and more spectrum is demanded to satisfy the exponential wireless services growing; the actual wireless networks need to be updated to satisfy the QoS demanded by the new services.

As alternative to contribute to fulfill that demand, the implementation of dynamic spectrum sharing technics are a possible alternative. The spectrum sharing could be defined as the scenario where two or more radio systems are using the same frequency band to receive and/or transmit [2]; one of the users is defined as *primary user*, and the other(s) are named as *secondary user(s)*. The spectrum sharing could be implemented using the so called technology Cognitive Radio (CR). The CR allows that a secondary user can utilize a spectrum space (named as White Space), while the spectrum is unused by the primary user. However, the CR implementation is not an easy assignment; there is needed that the electronic receiver/transmitter has the capacity to sense and known the environment where the device is operating; sensing the spectrum, the device could detect some spectrum portion unused (WS). Once these WS was detected, an algorithm to enable the receiving/transmitting capacity could start, defining the technical parameter to proceed with the link operation. Once the sharing spectrum is operating, one of the most important requirements is that the secondary users will not interfere to the primary user operation.

From a regulatory point of view, actually there is not a regulation or rules proposal for a CR system operation. The development, implementation and effectiveness of the CR systems in a middle or long term, will depend of the markets evolution, trials results, as well as from the generation and demand for new applications and new chain values.

Basically, CR exploit that some frequency bands are unused in some time intervals during the transmission/reception process. However, the CR in not the only way to implement the spectrum sharing strategy. The operation of some actual wireless systems where the frequencies bands are unused in some geographical region, open new ways to develop and operate a spectrum sharing strategy.

Traditionally, the spectrum offered for wireless services and applications has two options:

- Licensed Frequency bands.
- Free frequency bands.

The technological improvements allows mixed models, allowing share spectrum with several operational requirements. Some of these models are the Licensed Sharing Access (LSA) and the Opportunistic Spectrum Access (OSA).

Trials for sharing spectrum in 2.3 GHz band had been implemented in Finland [14], using a LSA between wireless cameras (PMSE, Programming-making and special events), and mobile operators networks (MNO). The 2.3 GHz frequency band could be used by MNO when wireless cameras (incumbents) do not require it, which is often the case in many geographical locations in Finland. To enable the control links coordination a geolocation databases can be used. A similar trial in Rome, Italy was implemented; the Italian Ministry of Economic Development and the Joint Research Centre of the European Commission have stated a pilot project on the sharing of the radio spectrum in the 2.3-2.4 GHz band, using the LSA alternative too.

The geo-localized databases used, is one of the most cited alternative in several trials and proofs around the world; in a sharing spectrum system using a geo-localized database, the potential secondary user can verify the WS spectrum available around their geo-graphical position, by accessing to geo-localized database, where all the technical information regarding to the licensed frequencies are saved.

There are several specialists and international organizations showing a skeptical position regarding to the benefits that spectrum sharing could offer. For one side, they see as a good point that an operator could access to more spectrum to increase their capacity to offer services; at the same time, they see as a risk that an operator could monopolize the market, accessing to more and more spectrum.

The licensed operation, regulatory aspects, and very clear and pragmatics rules are recommended as a base to evolution a sharing spectrum alternatives, operating always as a complementary strategy to access for more spectrum.

The International Telecommunications Union (ITU), has stablished some guidelines for spectrum sharing using technologies applying CR [4][5]. According with the ITU, a CR system could defined as a radio system that use some technology to get knowledge about their environment and operational conditions, over the operation rules stablished and the protocols used, so that the predefined objectives be achieved; at the same time, the system are capable to learn from the obtained results. In general, a CR system can:

a) Get information from the surrounding environment.

b) Make decisions and adjust their operation conditions.

c) Learn from the obtained results.

According with GSMA, the sharing spectrum is defined as the collective use of an electromagnetic spectrum portion by two or more users. From a regulatory point of view, the sharing mechanism could be licensed or not [1].

The paper is organized as next: In Section II a State of Art is exposed, and some studies and results around the world are cited. In III the TVWS for Mexico are analyzed as a potential resource for spectrum sharing alternative, using the TVWS spectrum available in the country; data rates and population coverage are estimated. In section IV the ITU recommendation are applied to calculate the exclusion area for the C Band earth stations located in Mexico; then, using the data obtained, an estimation about the amount of potential cities that could use the C band for sharing spectrum applications are obtained.

II. STATE OF ART.

Actually, around the world there are several studies and trials analyzing and evaluating the TVWS as an alternative to provide mobile and fixed wireless services, additional to the WiFi and cellular networks. The TV White Spaces (TVWS) spectrum offers a lot of advantages in enhancing the mobile systems capacity; in [16] TVWS capability is explored for rural areas to provide internet access, addressing the problem by mean of distance distribution to provide a good quality of service. In [15], a field trial results for a WiFi based spectrum sharing technology in TVWS is detailed; the trial use a Dynamic Spectrum Management (DMS) platform and was dome in Melville, NY, in the USA. In [17], a network architecture integrated by an hybrid TVWS and WiFi backhaul is described. The application of cognitive radio system concepts for the off-loading operation of Long Term Evolution (LTE) networks by the opportunistic use of the TVWS are described in [18].

Regarding satellite C bands sharing spectrum, in [12], a sharing spectrum between IMT (International Mobile Telecommunication) 2000 (Wimax) and satellite networks systems operating in the C band is detailed; the study conclude that this sharing scheme could be viable in regions where there is low density of earth station deployments (typically rural zones). In [17] spectrum sharing between heterogeneous systems, such cellular systems, radars and satellite is studied, showing that an exclusion zones are required to protect the satellite services. The conventional and extended C-band fixed satellite service (FSS) are considered.

The present paper evaluate the spectrum sharing alternative to increase the spectrum available for wireless services in Mexico; the ITU recommendation were applied for the available TVWS spectrum. Also, the exclusion areas for the C band earth stations in México are calculated; using these data, the sharing spectrum impact for some cities along the country are evaluated, considering the potential inhabitants that could be coverage.

III. TVWS IN MEXICO

For Mexico, the TVWS as a resource for additional spectrum in sharing schemes could be a viable alternative; the TVWS could be a very important source for extra spectrum in several terrestrial wireless systems. The total TVWS spectrum available was estimated for all the Mexican states; the values are showed in Figure 1. As many other countries, in Mexico some rural regions have low internet services access. This fact represent one of the most important challenge to solve for the government; regarding the Internet access, in Table I, the Internet access for some states are listed; as we can see, there are states with less than 30% internet access for the rural population.

Using the data provided, the TVWS spectrum for the states listed in Table I are added. A spectrum scheme that allows to use these spectrum, could be a mean to contribute to find a solution for the internet access in rural zones.

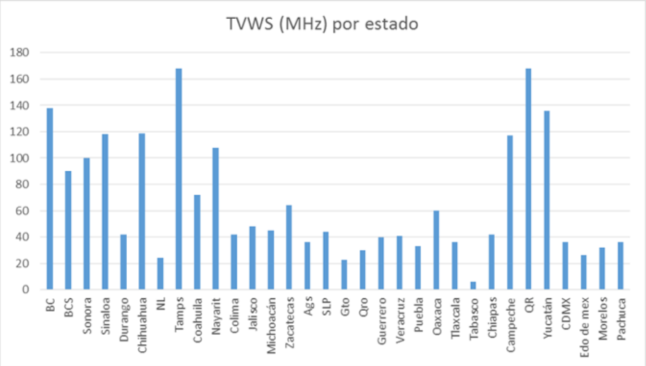

Figure 1. TVWS spectrum. Mexican states.

Focusing in the rural access, in Table I are showed the internet access percentage for urban and rural population in some states, showing the spectrum available by TVWS too. A sharing spectrum approach using the TVWS available could be an option to improve the internet access (rates and penetration) for the people of these states.

For a rural scenario, e.g., Chiapas state, a geographical spectrum sharing strategy is analyzed. The total TVWS channels for this state is almost seven channels; using the

ITU-802.22 wireless standard, with a 6 MHz channel bandwidth, an antenna high of 10m, Effective Isotropic Radiated Power (EIRP) of 40 mW, the coverage distance and the data rate was calculated; the obtained values are showed in Table II.

TABLE I. INTERNET ACCESS. SOME MEXICAN STATES

Internet access. % inhabitants			Average TVWS (MHz)
State	Urban	Rural	
Guerrero	63	27	40
Chiapas	51	24	41
Veracruz	66	33	40
Oaxaca	60	36	38
Chihuahua	76	37	120
Tamaulipas	74	38	164
Quintana Roo	82	46	164

Nevertheless, most of the trials reported have been implemented in rural zones, the TVWS could be a very useful option to support the urban Cellular and WiFi networks during peak hours operation (typically a network saturation issue). One alternative is to use the spectrum offered by TVWS to implement an offloading scheme.

The offloading alternative allows relieving a congested mobile data network with additional capacity from TVWS spectrum available might be a useful tool to contribute for the networks saturation problem).

TABLE II. COVERAGE DISTANCE AND DOWNLINK RATE FOR A TVWS CHANNEL (6 MHZ)

Distance (km	Average data rate (Mbps)	
	DL	UL
0.38	7.21	7.81
1.97	6.42	7.64
3.87	4.68	4.61
7.57	4.09	3.16
7.58	5.41	4.37

In Table III are listed 9 urban cities located along the Mexican territory, indicating the average TVWS spectrum available for each state. There are indicated the available data rate for each city with 4G technology, the TVWS available (MHz), (in parenthesis there are indicated the continuous spectrum available), the antenna technology available, and in the last column, the potential data rate is estimated using the data collected in [19] using the TVWS available.

TABLE III. DOWNLINK RATE FOR A TVWS (CONTINUOUS SPECTRUM) FOR SOME ESTATES.

City	Data rate 4G Mbps	TVWS		
		BW (MHz)	MIMO	Data Rate(Mbps)
Ags.	21.55	36 (10)	no 2x2	42 84
Juárez	32	120 (20)	2x2	168
Cd. México	26.3	24 (20)	2x2	168
Mty	26.58	36 (20)	2x2	168
Puebla	22.88	30 (20)	2x2	168
Qro	27.49	30 (20)	2x2	168
SLP	25.8	60 (10)	no 2x2	42 84
Tijuana	26.27	102(20)	2x2	168
Toluca	25.41	24 (20)	2x2	168

Analyzing an hypothetical offloading scheme impact applying the TVWS available for each city, in the same Table are showed the additional data rate achieved using the TVWS spectrum available; the data rate obtained was calculated using the continuous spectrum available (value between parenthesis), by simulation applying the parameters for the 802.22 standard. As we can see, the offloading alternative using the available TVWS spectrum could be a potential option to increase the cellular networks capacity.

IV. C BAND IN MEXICO

The C band (3.4-4.2 GHz) and the extended C band (3.4-3.7GHz), are mainly used for fixed satellite services (FSS). The sharing spectrum alternative in these bands for use in mobile terrestrial services is an open dilemma; there are some critics regarding to the implementation, and others that support the idea.

Among the supporters are the mobile services operators, showing and detailing analysis and operational conditions to justify it; at the other side, the satellite operators basically argue that the potential interference generated from a mobile terrestrial applications will cause a serious signal degradation, that could cause severe damage over the satellite link. In general, the satellite receiver must be designed with a higher sensibility, in order to detect the small power signals delivered from the satellites; this high sensitivity represent a big challenge for a spectrum sharing spectrum scheme.

The ITU-R P.452-12 stablishes the operational conditions for a satellite base station in order to allow the spectrum sharing alternative with terrestrial services; these conditions are defined for the 100 MHz to 205 GHz band. In [12], are exposed an analysis applying the propagation models described in ITU-R P.452-12.

For the long term cases, the propagation is calculated over a smooth earth surface, utilizing the propagation model described in section 4.3 of the ITU-R P.452-12; this model includes the effects of building loses and clutter and the topography of the surrounding obstacles.

For the short-term propagation, the ducting mode of propagation model described in section 4.5 of the same recommendation had been utilized. Applying the before mentioned propagation models, the minimum separation distance between and FSS station and a Base Station were estimated. The obtained values are showed in Table IV.

With the delimited protection areas, and considering the geographical coordinates for all the satellite earth station operating in Mexico in the C and Extended C band, an estimation was done for the potential cities where these bands could be available to implement a sharing spectrum scheme.

Using the geographical satellite earth station localization for 210 stations in Mexico, a sample for cities with more than 5000 inhabitants were evaluates to determine if these cities are localized inside or not, of the coverage protection area defined for any satellite earth station. The analysis was focused on the states with more rural population (and less earth station density).

In Figure 2 there is showed a graphic representation for the Chiapas state evaluation. The earth stations were localized over the map, and a coverage area was determined for each station; this area was calculated using the minimum distance required to avoid harmful interference (Table III).

TABLE IV. MINIMUM SEPARATION DISTANCE

Protection criteria for the FSS (I/N, dB)	Required Isolate (dB)	Minimun separation distance (km)	
		Long term	Short term
-1.3	165.9		140
-12.2	176.8	55	
-15.5	179.8	70	

The cities localized outside the shadowing area, could be candidate to use a sharing spectrum alternative using the C band.

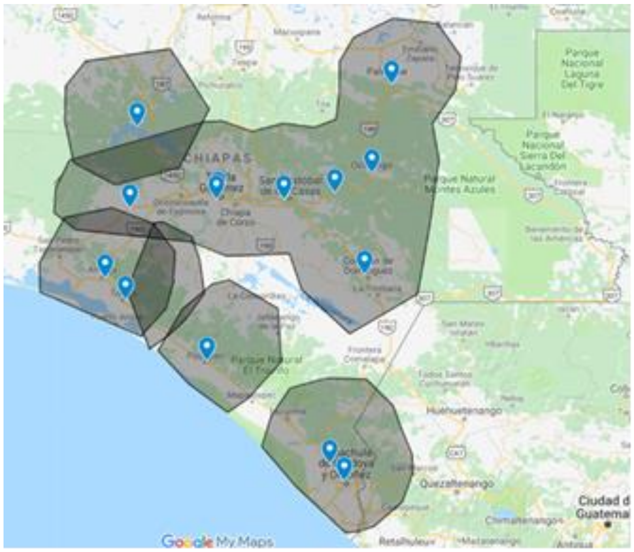

Figure 2. Coverage area for satellite earth stations for Chiapas.

According to separation distance around the satellite earth station showed in Table III, coverage areas were obtained for 55, 70 y 144 km radium values. The cities evaluated were classified as showed in Table IV: towns with more than 5000 habitants, cities between 50,000 and 5,000, cities between 20,000 and 5,000 and cities between 10,000 and 5,000.

The results for Chiapas state analysis are detailed in Table V and in the Figure 3. In these are showed that for a minimum separation distance (55 km), around the 38% of cities with 5000-10000 habitants might use the C band in a spectrum sharing configuration. In general, the results observed for the Chiapas sates reveals that as the city population decrease, the city have a bigger possibility to implement a sharing spectrum scheme using the C band. For the 140 km protection distance, the amount for candidate cities are less significant

TABLE V. TOTAL CITIES LOCATED OUT OF THE PROTECTION AREA FOR SEVERAL SEPARATION DISTANCES.

Inh/city	Minimum separation distance (km)		
	55	70	140
>5000	22.22%	11.11%	1.8%
50,000-5000	25.88%	12.94%	2.3%
20,000-5000	30.95%	16.66%	4.7%
10,000-5000	38.09%	19.04%	4.7%

Similar analysis was done for a sample integrated by 10 states; 5 of these states are similar to Chiapas (with great rural population), and the other 5 states with higher urban population.

The results obtained are showed in Figure 4. The obtained cities percentages have a similar tendency that the showed for Chiapas, but having less values.

V. CONCLUSIONS AND FUTURE WORK

A potential use for spectrum sharing using the C band and the TVWS channels was described. For the TVWS case, there are a lot of spectrum to be used for potential sharing spectrum schemes, allowing increase the terrestrial systems capacity.

Applying some technical considerations from ITU Recommendation, data rates were estimated for some states, along the Mexican territory. This alternative should be a very useful resource to solve the internet service access for the rural zones. By the other hand, the potential C band use for spectrum sharing schemes was less attractive than the TVWS option. The high satellite receiver sensitivity condition, require protection areas to avoid harmful interference. Perhaps the secondary use for fixed terrestrial services could be more feasible, but the potential cities out of the calculated protection areas are a few. Future work could include the sharing spectrum evaluation in others bands, and analyzing dynamic spectrum strategies.

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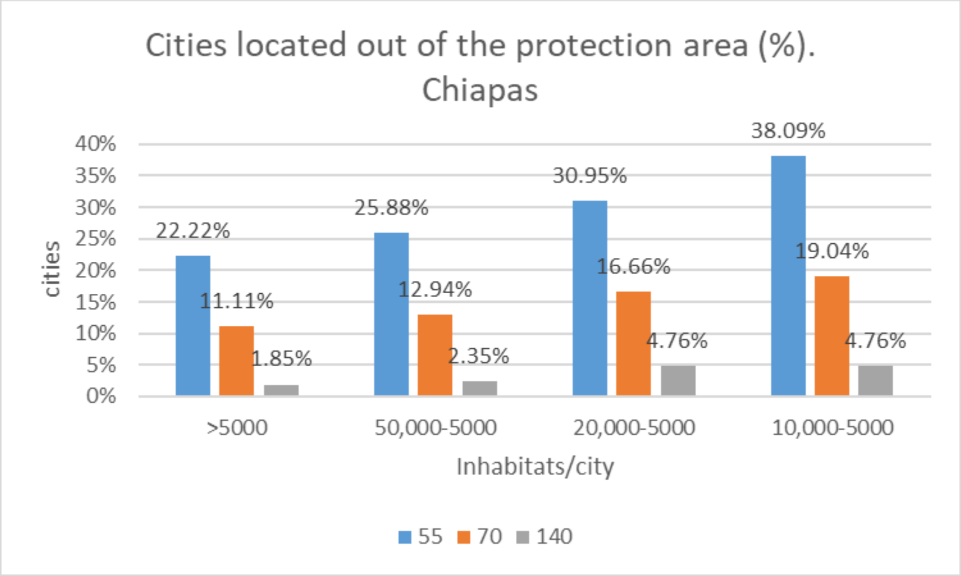

Figure 3. Cities located out of the protection area for the minimum distances values recommended by the ITU. Chiapas state.

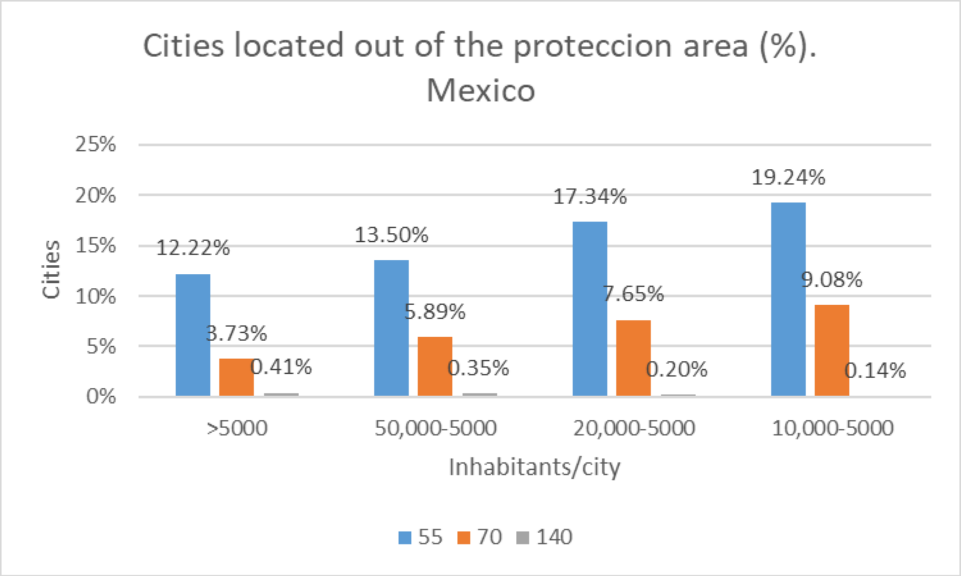

Figure 4. Cities located out of the protection area for the minimum distances values recommendated by the ITU. Mexico.