Capacity Analysis of a Delay and Disruption Tolerant Network in the Amazon Basin

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Abstract—**Due to the regional characteristics of the Amazon, waterborne transportation is prevalent. Therefore, the deployment of Vehicular ad hoc networks (VANETs) using boats is considered a technological option to interconnect the region. In this context, contacts between boats can be used to obtain an increased capillarity and efficiency of the network. This paper presents an experimental performance evaluation of wireless communication, using IEEE 802.11 b/g, between boats in the Negro river. The main goal is to characterize the transmission and the contacts of boats, aiming at evaluating the goodput of a delay tolerant network (DTN) formed by boats in the Amazon basin. The results of our experiments show the feasibility of data traffic between boats with the common speed in the region. Combining the experimental results with the schedule information of regular boat lines in the waterways of west Amazon, we estimate the capacity of this large-scale DTN.**

I. INTRODUCTION

In the Amazon region, due to the predominance of rivers and forests, transportation is mainly by water. About 65% of cities in the region use the waterborne transport, while airplanes are used by 21% and the road transportation by only 13%. As a consequence, the economic development of the region is strongly dependent on load transportation. Moreover, several cities in the Amazon state are technologically excluded due to economic, geographical, or technical unfeasibility aspects. Building a communication infrastructure in these cities or villages far away from the metropolis implies high costs. The focus of this work is to analyze an alternative to connect these remotes areas to urban centers, using the boats as information carriers. Due to these large sparse areas, it is difficult to provide connectivity anywhere and anytime in this kind of scenario. Thus, Delay and Disruption Tolerant Networks (DTN) [1] arise as a promising low-cost alternative to interconnect those remote small cities.

The main idea of this paper lies in employing a hybrid Vehicular Ad hoc Network (VANET) [2], where boats transport data and use opportunistic communications to spread information all over the Amazon basin. Hence, boats can communicate with a fixed infrastructure at the city ports, as well as connect to other boats, whenever there is a contact opportunity. Then, a boat receives and stores the information sent during the contact time. Following this procedure, information can travel from boat to boat until reaching its destination [3]. The goal is to exchange data with other boats to increase the probability that a given information reaches its destination. Another advantage is to reduce the communication delay for villages, where the number of visiting boats is small. In this context, our first goal is to evaluate and characterize the data transfer capacity of this large-scale opportunistic DTN in the Amazon basin. In the literature, there are some efforts to characterize the contact time and the capacity of DTNs based on opportunistic communications, however, most of these works deal with totally different scenarios, such as automobile VANETs [4], [5] or a rollerblade tour in Paris [6].

In this paper, we aim at estimating an upper bound for the total capacity of a DTN composed by all the boats in the Amazon basin. Thus, the main contributions of this paper are: first, we evaluate, through field experiments, the contact time and the transmission capacity of boats in the Negro river, in different scenarios; second, we derive a generic expression for the amount of traffic that can be transferred when two boats cross each other, based on our experimental results. Then, we can build a model to compute the contact time for all boats in the considered region of the Amazon basin, based on the boat schedules provided by the government. Finally, based on the generic expression for data transfer capacity and the contact time model we calculate the total capacity of a DTN in the Amazon basin. Our results reveal a significant network data transfer capacity, of 186 GB/week confirming the great potential for improving communication in the Amazon state. Another interesting result shows that, indeed, the contact time and the transmission capacity in waterway scenarios is fundamentally different from automobile VANETs in urban scenarios.

The rest of the paper is organized as follows. Section II presents the related work. In Section III, we describe the environment and the characteristics of the experiments, and the results. In Section IV we calculate the capacity of the DTN in the Amazon basin. Section V concludes the paper and discusses future work.

II. RELATED WORK

Several works empirically analyze the data transfer capacity in vehicular networks considering different scenarios. In [5], the authors investigate Internet access in highways using IEEE

802.11b. The vehicles move in opposite directions, with speeds ranging from 80 to 180 km/h, crossing two access points at the roadside. They use UDP and TCP protocols with packets of 1,250 bytes. Experimental results show that the average amount of data that transferred to the infrastructure varies from 8.8 to 3.7 Mbytes and 6 to 1.5 Mbytes, for UDP and TCP, respectively.

Rubinstein *et al.* [4] perform experiments on a straight road of 400 meters long, in the campus of UFRJ, to evaluate the data transfer capacity of two vehicles crossing each other. The cars move in opposite directions, with speeds varying from 20 km/h to 60 km/h. The testbed consisted of two laptops, running a client in one car and a server in the other one. The two laptops were equipped with IEEE 802.11 a/g cards and were configured in the ad hoc mode. In the experiments, they analyzed the performance of UDP and TCP, for different packet sizes. The results show that, using IEEE 802.11g and UDP protocol, the average contact time between the two vehicles varied from 45.17 to 10.83 seconds and the average amount of data transferred ranges from 13 to 1.6 Mbytes.

In [7], the authors propose a mathematical model to predict the amount of data transferred in a DTN composed of a single boat and a fixed access point (AP) placed at the riverside. The key idea is that small villages along the river can communicate, using the boat to carry their data. In their experimental scenario, a boat passes by a fixed access point attached to a tower, 40 meters high, located the Sustainable Reserve of Tupé - Julião Colony on the banks of Negro river. The authors analyze the goodput and the received power *(Received Signal Strength Indication - RSSI)* using TCP to transfer data during a single contact. The boat sailed at 10 and 30 km/h, using IEEE 802.11n. The distance between the boat and the tower is approximately 200 meters. Their results show that for speeds of 10 and 30 km/h the average amount of data transferred between the boat and the AP is 184 and 55 Mbytes, respectively.

Table I summarizes the main characteristics of the related works and the present paper. The symbol "-" indicates that a specific characteristic was not identified in the proposal.

TABLE I
SUMMARY OF THE RELATED WORK.

Parameter	**Ott** *et al.* [5]	**Rubinstein** *et al.* [4]	**Neto** *et al.* [7]	**Present paper**
Vehicle	Car	Car	Boat	Boat
Speed	80-180 km/h	20, 40, 60 km/h	10, 20, 30 km/h	20, 30, 40, 50, 58 mph
Communication	V2I	V2V	V2I	V2V
Technology	802.11b	802.11b/a	802.11n	802.11b/g
Packet size (Bytes)	1250	150, 500, 1460	-	150, 500, 1460, 2340
Protocol	TCP, UDP	TCP, UDP	TCP	UDP
Distance (m)	-	less than 5	196	100

Both [5] and [4] evaluate the capacity of VANETs in similar scenarios, where the most important characteristic is that nodes represent cars in an urban environment. In this work, we analyze VANETs composed of boats in substantially different scenarios. Therefore, these scenarios present singular characteristics such as mobility pattern, network density, topology dynamics, and signal propagation over the river bed. In [7], the authors investigate the same type of VANET, namely, based on boats, however, there are some important differences from our analysis. First, we address the communication between boats, because our main goal is to improve network efficiency by allowing boats to spread information all over the Amazon basin, where roads are not an option. Second, the two experiments use different parameters such as the speed, transport protocol, and packet size. We believe that in our work we tried to emulate a more realistic scenario, using usual local boat speeds, and assessing the impact of these parameters. Additionally, based on our experimental results, we derive a model to estimate an upper bound to the data transfer capacity of a DTN in the Amazon river system.

III. MEASURING THE CAPACITY OF BOAT CONTACTS

The experiments were performed on the banks of the Negro river, as shown in Figure 1(a), between the communities of Livramento and Nossa Senhora de Fátima, Tarumãzinho, Manaus - AM. The period of the year when the experiments were performed corresponds to the end of the flooding season. The length of Negro river is 1700 km, its width ranging from 2 to 24 km. We used small boats in our experiments.

Before starting the experiment, the two boats were far enough to be outside the radio range of each other. The boats move in opposite directions, parallel to the river, crossing each other with constant speeds of 20, 30, 40, 50, and 58 mph. The equipment used in the experiment was: (a) Nokia N900 smartphones with the Linux distribution - Maemo 5; (b) D-Link DIR-320 wireless routers; (c) external omnidirectional antennas (2.4 GHz, 12 dBi); (d) 32 GB flash drives attached to the USB port of the router; (e) voltage regulators (12 volts to 5 volts); (f) 12 V batteries. To measure the goodput of the network, we used Iperf software, version 2.0.4. The measurements were performed in an extension of 2.5 km of the Negro river, where there was little boat traffic and no other IEEE 802.11 network was operating.

(a) The Negro river.

(b) Wireless router attached to the boat.

Fig. 1. Scenario of the field experiments.

A. *Specificities of the Experiments*

Besides the scenario described above, many factors can influence the results of the experiments. Some of them are technical deployment issues, like the place where the access point was attached, while others are external factors, over which we have no control, like the weather conditions. The specific characteristics of our experiments are summarized below:

Weather and river conditions: temperature was 26 °C, relative humidity of 78%, wind speed ranging 6-8 km/h, and river velocity of 2 km/h. These conditions correspond to the average weather and river conditions in the region.

AP position: the highest is the AP position, the better is the performance of the radio. Thus, access points were placed at the highest point of the boat, known as *Tolder*. In our boat, it corresponded to a height of 2.67 meters above the water level, in the front of the boat, as illustrated in Figure 1(b). The mobile node (smartphone) was inside the boat with the personal.

Crossing distance: the distance between boats that cross one another plays a crucial role to determine the amount of data that can be transferred. The shortest is the distance, the longer is the contact time and the strongest is the signal strength at the receiver. At the same time, there are safety issues that define a safe distance below which it is too dangerous for the boats to cross. Therefore, in our experiments, we adopt the recommended safe distance of 100 meters. Thus, from this viewpoint we estimate an upper bound for the transmission capacity, since this is the closest a boat can cross another.

Each boat had an access point as a server and N900 smartphone as a client. Thus, data was transferred from the client in one boat to the server in the other boat. Before reaching the radio range of the other boat, the client starts its transmission, to guarantee that once it manages to connect to the AP in the other boat, the transmission starts. To avoid interference between channels, we used channels 1 and 6.

Every second we recorded the amount of data transferred and the bandwidth between client and server in a log file. The speed of the boats ranges from 20 to 58 mph. We use UDP instead of TCP because TCP is not suitable for wireless links with high error rates, since it considers losses due to link errors as a sign of congestion. We have repeated three times the same experiment, one for each configuration of boat speed and packet size. Table II summarizes the main parameters used in the experiments.

TABLE II
MAIN MEASUREMENT SETUP PARAMETERS.

Parameter	**Value**
IP Address	Fixed
ARP	Manual
ESSID	Fixed
Channel	Fixed (1 and 6)
Wireless Tecnology	IEEE 802.11 b/g
Transport Protocol	UDP
Speed	20, 30, 40, 50, 58
Packet Size (bytes)	150, 500, 1460, 2340

B. Results

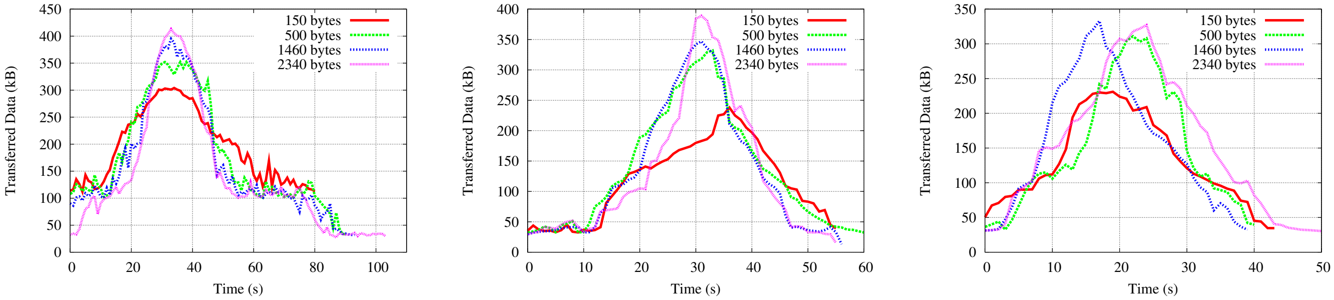
In our analysis, we define: (i) the contact time as the time interval between the first and the last data packet correctly received by the boats; (ii) goodput as the effective flow of data without retransmissions, at the application level, and (iii) the peak rate as the maximum rate of data transferred between boats.

Table III summarizes the main results of the experiment. Based on this table, we can calculate the average contact time of each scenario. The standard deviation is denoted by σ, and it is computed over the three repetitions of the experiment. For 20 mph speed, the average contact time is approximately 92 seconds. For the other scenarios, the contact time is inversely proportional to the relative velocity of the boats, as expected. For example, when we double the speed to 40 mph, the average contact time is 43 seconds, and increasing the speed by a factor of 3 (58 mph), the contact time is 29 seconds. It is worth mentioning that the coverage area remains approximately the same value, around some 760 meters, independently of the speed. The measurements show the relationship between the speed of the boat, the packet size, and the amount of data transferred. The standard deviation of the contact time and amount of data transferred can be considered large with respect to the average values. For the contact time, especially for high speeds (50 and 58 mph), it achieves more than 20%. The main reason for this variation is the increasing balance of the boat produced by the river agitation, small waves and wind experienced in the Negro river.

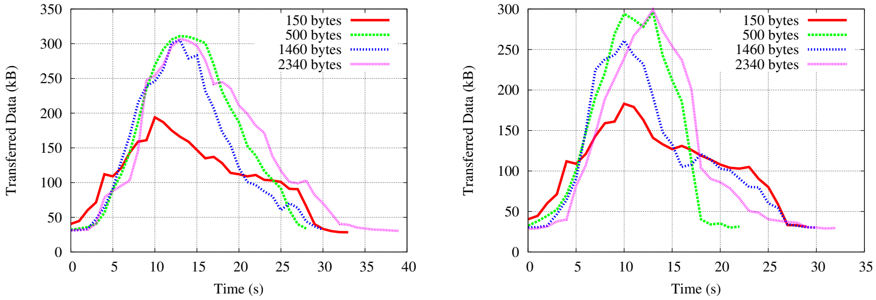
TABLE III
AVERAGE CONTACT TIME, TRANSFERRED DATA AND GOODPUT BETWEEN BOATS OVER UDP AND IEEE 802.11 B/G.

Speed (mph)	**Packet Size (Bytes)**	**Contact Time (Seconds)**	**Transferred Data (Mbytes)**	**Goodput (Mbps)**
20	**150**	80 ($\sigma = 4.58$)	10.15 ($\sigma = 0.82$)	1.96 ($\sigma = 0.03$)
	500	90 ($\sigma = 3.46$)	11.55 ($\sigma = 1.32$)	1.68 ($\sigma = 0.03$)
	1,460	93 ($\sigma = 7.81$)	13.77 ($\sigma = 1.72$)	1.69 ($\sigma = 0.05$)
	2,340	103 ($\sigma = 8.54$)	15.49 ($\sigma = 0.82$)	1.91 ($\sigma = 0.04$)
30	**150**	55 ($\sigma = 3.61$)	6.69 ($\sigma = 0.21$)	0.77 ($\sigma = 0.04$)
	500	61 ($\sigma = 2.65$)	7.34 ($\sigma = 0.12$)	1.12 ($\sigma = 0.05$)
	1,460	56 ($\sigma = 5.29$)	7.44 ($\sigma = 0.04$)	1.16 ($\sigma = 0.02$)
	2,340	55 ($\sigma = 7.81$)	7.52 ($\sigma = 0.25$)	1.13 ($\sigma = 0.05$)
40	**150**	43 ($\sigma = 2.65$)	5.80 ($\sigma = 0.14$)	1.66 ($\sigma = 0.09$)
	500	40 ($\sigma = 3.61$)	6.12 ($\sigma = 0.21$)	1.91 ($\sigma = 0.03$)
	1,460	39 ($\sigma = 5.29$)	6.36 ($\sigma = 0.14$)	1.70 ($\sigma = 0.06$)
	2,340	50 ($\sigma = 3.46$)	7.81 ($\sigma = 0.14$)	1.93 ($\sigma = 0.02$)
50	**150**	33 ($\sigma = 1.73$)	3.78 ($\sigma = 0.15$)	1.19 ($\sigma = 0.02$)
	500	28 ($\sigma = 3.61$)	4.20 ($\sigma = 0.05$)	1.25 ($\sigma = 0.06$)
	1,460	30 ($\sigma = 4.36$)	4.22 ($\sigma = 0.12$)	1.41 ($\sigma = 0.03$)
	2,340	39 ($\sigma = 7.55$)	4.37 ($\sigma = 0.17$)	1.40 ($\sigma = 0.04$)
58	**150**	29 ($\sigma = 8.00$)	3.13 ($\sigma = 0.05$)	1.48 ($\sigma = 0.09$)
	500	22 ($\sigma = 4.36$)	3.23 ($\sigma = 0.08$)	1.84 ($\sigma = 0.06$)
	1,460	30 ($\sigma = 8.54$)	3.47 ($\sigma = 0.06$)	1.54 ($\sigma = 0.06$)
	2,340	32 ($\sigma = 11.14$)	3.73 ($\sigma = 0.06$)	1.72 ($\sigma = 0.04$)

Figure 2 shows the average amount of data transferred between the boats as a function of time. Note that besides reducing the contact time, increasing the speed also reduces the peak rate. For instance, for twice the speed (Figures 2(a) and 2(c)), the peak rate decreases by approximately 20%. This characteristic further contributes to the reduction in the capacity of data transfer between two boats at higher speed.



(a) Average goodput at 20 mph.
(b) Average goodput at 30 mph.
(c) Average goodput at 40 mph.



(d) Average goodput at 50 mph.
(e) Average goodput at 58 mph.

Fig. 2. Data transfer over UDP between two boats crossing at different speeds.

It is interesting to note that most of the data is transferred before the second half of the contact period, that is, the peak is slightly shifted to the left. For example, for speeds of 50 mph and 58 mph, Figures 2(d) and 2(e) respectively, 64% of the data are transferred during the first half of contact time. This effect occurs due to the multiple rates feature of 802.11. The transmission rate is set to the maximum value at the beginning of contact, and it is quickly reduced to the minimum rate, because the distance between the boats does not allow higher rates. As the two boats approach the rate progressively increases. Accordingly, during the first half of contact period, while the rate is increasing, all frames sent are being received properly. After they cross, the boats start to go away and the rate of 802.11 decreases as the frame loss rate increases. Thus, in this second half, part of the frames is lost before adapting to a more appropriate transmission rate. The same behavior has been observed in the experiments with cars [4].

Another interesting result can be observed in Figure 2. Clearly, during the contact period, there is an area of higher data transfer capacity, for each speed. This area is basically defined by the distance between the boats and it is located around the peak region. This means that the accuracy in the contact time estimation is less important, namely, if the contact time is 92 or 85 seconds, it has small impact on the estimated capacity. The most important thing is to know that the boat had 65 seconds within the higher capacity area. In Figure 2 is possible to identify this area for each boat speed. For 20 mph, the higher capacity area comprises approximately 76% of the contact time and is responsible for 90% of the data transferred. For 30, 40, 50 and 58 mph, the area responsible for 90% of the transmission capacity is approximately 70%, 70%, 76% and 75% of contact time, respectively. Therefore, this result allows a larger margin of error in the contact time estimate. This is an important result, especially for wireless waterway networks, in which there are many parameters that influence the transmission capacity, as described in Section III-A. Hence, this larger margin of error can accommodate small variations in these parameters without losing significant accuracy in the calculation of the capacity. Consequently, this result also permits to generalize the results to obtain an estimate of the capacity of the network as a whole, as will be presented in the next section.

It is worth mentioning that the contact time and the amount of transferred data measured in our work is higher than in [4]. The relation between average contact time measured in our work ($v = 64$ km/h) with the one measured in [4] ($v = 60$ km/h) is 3.4. Likewise, the relationship between the averages of the amount of data transferred is 3.8. This is evidence that the contact time and transfer capacity of two boats crossing in a river are fundamentally different than two cars crossing in an urban street.

IV. CAPACITY OF A DTN IN THE AMAZON BASIN

The study of the capacity of a DTN in the Amazon basin was produced using real data of boat schedules, from AHIMOC, combined with our experimental measurements performed on the Negro river, presented above. In this study, we considered cargo transport boats, mixed transport boats (cargo and passenger), and passenger boats. The scheduling information, for every boat, includes name, type, source and destination, date and time of departure, distance traveled, frequency of travel and the direction in the river channel. The channels (Figure 3) are important pathways of social and economic transportation for the state of Amazon. These channels connect cities and villages all over the state and provide means to products produced in the PIM to be transported. Table IV lists the river channels we consider in our analysis.

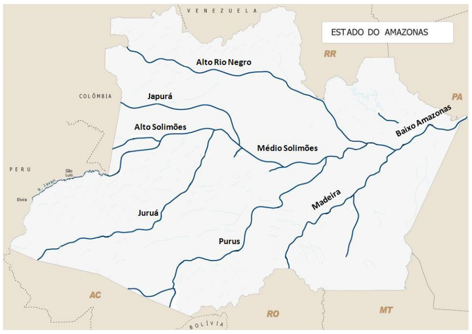


Fig. 3. River channels in the Western Amazon.

TABLE IV
MAIN RIVER CHANNELS IN THE WESTERN AMAZON.

River Channels	Routes
Alto Rio Negro	Manaus - São Gabriel da Cachoeira
Alto Solimões	Manaus - Tabatinga
Baixo Amazonas	Manaus - Santarém - Belém
Juruá	Manaus - Eirunepé
Madeira	Manaus - Porto Velho
Médio Solimões	Manaus - Coari - Tefé
Purus	Manaus - Boca do Acre

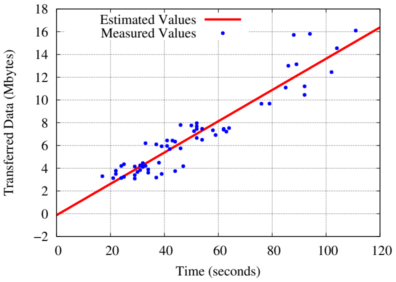
We aim at estimating the total capacity of a DTN composed by all of the boats in these channels. Since we cannot measure the transmission capacity for all boats in the Amazon basin, the first step is to derive a generic expression for the amount of traffic that can be transferred when two boats cross each other, based on our experimental results. Then, we calculate, for every channel, the amount of boats, their speed, and the distance traveled, to model the contact time. Finally, based on the expression for data transfer capacity and the contact time we calculate the total capacity of an Amazon basin DTN, which corresponds to an upper bound of the total traffic that can be transferred among the boats.

A. Data transfer during a contact

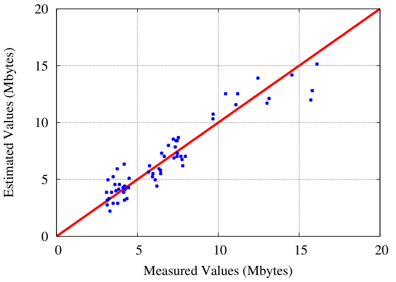
Based on the contact time and amount of data transferred in our experiments of two crossing boats on the Negro river, we used statistical linear regression [8] to analyze the samples and fit a regression line $f(t)$ = a * t + b, obtaining the parameters $a = 0.13$ and $b = -0.12$ (Figure 4(a)). This equation is a generic expression that estimate the total amount of data transferred between two boats that cross each other. Thus, the amount of data transferred and contact time can be estimated by the function:

$$f(t) = 0.13 * t - 0.12, \qquad (1)$$

where t is the contact time in seconds and $f(t)$ the amount of data transferred between the boats in Mbytes.



(a) Transferred Data x Contact Time.



(b) Residual Graphic.

Fig. 4. Model Analysis.

In order to measure the accuracy of the generic expression we used the Root Mean Square Error (RMSE), R-Squared (R^2), and plotted a residual graph [9]. The metric RMSE evaluates the individual differences between the vector of estimated values $y(k+1)$ and actual values $\hat{y}(k+1)$ of data transferred between boats. The RMSE value was 1.14, which can be considered a low estimation error. The metric R^2 quantifies the output variation captured by the model, ranging from 0 (worst) to 1 (best). $R^2 \geqslant 0.8$ is considered a good value for the estimation [8]. We found for our model $R^2 = 0.89$.

Figure 4(b) shows the residual graph representing the output predicted by the generic expression (straight line) and the experimental values. Figure 4(b) shows that the experimental points are close to the predicted curve.

B. Modeling the contact time

We developed a model to calculate the contact time between all boats in the considered river channels (Table IV). Our model is based on the scheduling information and considers the following parameters:

- Quantity of boats (Q): total number of boats that travel in the river channels. Therefore, $Q = \sum_{i=1}^{N} Q_i$, where Q_i is the number of boats in channel i and N the number of channels.
- Average speed of boats (Vm): $Vm = \frac{\Delta s}{\Delta t}$, where Δs is the fluvial distance between Manaus and the other cities and Δt is the estimated travel time.
- Contact time (T_c) between two boats: defined in Section III-B, can be computed from the Uniform Motion (MU) equation, considering that boats move at constant

speed. Therefore, $S_Y = S_0 + V \times t, (V \neq 0)$, where S_0 is the position of the boat Y at time $t = 0$ and V is the speed. The condition that the boats are within the radio range of each other in our experiments[1] is given by the inequality 2 as:

$$|S_a - S_b| \leq 0.757, \tag{2}$$

where S_a and S_b give the position of node a and b, respectively and, we obtain instants when the two boats get into (t_1) and outside of (t_2) of radio range of each other. Thus, T_c = t_2 - t_1.

- Total distance traveled by boats ($Dist$): for each river channel, $Dist$ refers to the sum of the distances traveled by the boats in that channel. Hence, $Dist = \sum_{i=1}^{N} Dist_i$, where, $Dist_i$ is the distance traveled by boat i and N is the number of boats.

C. Capacity of DTNs in the Amazon Basin

The most economically important river channels are Baixo Amazonas, Madeira, Alto e Médio Solimões, because they are the main channels used to transport the products from the Industry Pole of Manaus (PIM, in the Portuguese acronym). In the Baixo Amazonas and Madeira channels, products are transported to supply the country, while Alto e Médio Solimões channels are responsible for transporting products to other countries. Médio Solimões channel have many boats, due to the oil found in the region. The other channels present a lower traffic of boats.

In order to estimate the upper bound for the capacity of a DTN in the Amazon Basin, we considered all the combinations of pairs of crossing boats, according to our model and the information from the boat schedules. The number of contacts and the contact time for each pair of crossing boats were derived using Inequality 2. We compute the total amount of data transferred replacing each contact time in Equation 1. Table V presents the results for each channel.

Given the 357 boats, we obtained 5,444 contacts between boats, with a total contact time of 406.22 hours. Therefore, the total data transfer capacity for a DTN in the Amazon basin is approximately 186 GB/week. The total distance traveled is 204,332 km.

TABLE V
ESTIMATED CAPACITY OF A DTN IN THE AMAZON.

River Channels	Number of Boats	Number of Contacts	Total Time of Contacts (Hours)	Total Data Transferred (GB)	Total Distance Travelled (km)
Alto Rio Negro	17	78	6.41	2.93	47,470
Baixo Amazonas	90	1,498	98.51	45.02	10,906
Madeira	23	178	29.96	13.69	16,948
Purus	22	98	6.76	3.08	17,199
Médio Solimões	59	888	61.09	27.92	23,970
Alto and Médio Solimões	77	1,585	126.67	57.89	50,004
Juruá and Médio Solimões	69	1,119	76.80	35.10	37,835

V. CONCLUSIONS AND FUTURE WORK

In this paper, we presented evaluation of the data transfer capacity of a DTN based on opportunistic communications among boats in the Amazon basin. First, we performed several experiments in the Negro river to assess the contact time and the transmission capacity of crossing boats. From the field results, we derived a generic expression to calculate the data transfer during boat contact. Then, using boat schedule information for the major river channels in the Amazon basin, we could predict the contact time for all boats. Finally, we used the generic expression to estimate an upper bound for data transfer capacity of the DTN. Results show the great potential of communications this network can achieve, with a transmission capacity of 186 GB/week. Thus, it is possible to develop applications and services that use the contact to improve communication in remote Amazon cities, producing development and modernizing the state. As future work, we plan to evaluate the amount of data transferred and the contact time using IEEE 802.11p equipment on board boats, through practical experiments and simulations.

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[1] Based on the average radio range measured in our experiments.