Nation Scale Mobile Ad Hoc Network for Normally Isolated Topologies

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***Abstract*—When network infrastructure is down after disasters such as hurricane Maria, in the face of extreme censorship and in remote areas without infrastructure novel solutions for large scale delay tolerant communications are needed. Nation Scale Mobile Ad Hoc Network, or NSHoc, enables smartphone users to request and receive content via opportunistic encounters at nation scale with no prior knowledge of network members and in sparse topologies where individual nodes may remain isolated for minutes or even hours at a time. We call such sparse topologies normally isolated. It does so by leveraging mobile ad hoc networks that rely on opportunistic encounters between users to distribute content. We use a custom simulator to test the system over two nation scale topologies, Puerto Rico and Syria. With 10K users, NSHoc can deliver over 95% of requested content to over 97% of users in 143 locations spread throughout Puerto Rico in less than 5 hours on average with a total throughput of .42 pieces of content per second. Significantly, these results are not simply the consequence of popular content being cached. We demonstrate that requests for unpopular content are also satisfied due to the benefits of ubiquitous caching. In addition, we show that NSHoc remains performant across a variety of topologies, mobility models and content distributions. No known prior work considers such large scale, sparse topologies. This work shows that MANETs are an attractive alternative for distributing content at nation scale in the face of infrastructure loss even when users are normally isolated.**

***Index Terms*—MANET, Delay Tolerant Networks, Human Mobility, P2P, Content Centric**

I. INTRODUCTION

Natural disasters, humanitarian crises, or censorship can all result in the loss of network infrastructure. Consider Puerto Rico after Hurricane Maria, the storm disabled entire cities' Internet infrastructures [7]. During the Arab Spring the entire nation of Egypt temporarily lost Internet connectivity in an effort to suppress communications [22]. In addition, there remain areas of the world where Internet infrastructure is unstable or nonexistent.

Each of these scenarios involves a large, disconnected topology. In some cases users may only ever be within WiFi range of one other user at a time. In the language of graph theory, the highest level of connectedness at any time would be two. See Figure 1 in Section II-A for an illustration. Existing solutions are not designed for such large, *normally isolated* topologies.

In our mobile ad hoc network based solution, called Nation Scale Mobile Ad Hoc Network, or NSHoc, both Interests and content spread via undirected broadcasts between users' smartphones that occur opportunistically when users are within WiFi range of one another. Each user has space allocated to store content on their phone so that they become a mobile content cache for other users. In content-centric networking this process is called ubiquitous caching. In this manner, a user who has never visited an Internet capable location can still receive their requested content from another user's cache. In fact, a user who has never met another user who has visited an Internet capable location can still receive their content because every user acts as a mobile content cache. Our system delivers over 99% of requested content to 10K users spread throughout Puerto Rico in less than 5 hours on average with a total throughput of .42 pieces of content per second.

We demonstrate that NSHoc remains performant even for unpopular content because of the benefits of ubiquitous caching (See Section VI for details). This fact is significant because it means that our system is not just caching the most popular content, but that user requests are influencing the content being cached in the network. Furthermore, by demonstrating that NSHoc is performant across a variety of mobility models and content distributions, we show the resilience of our approach.

While much research has been done in the MANET space in the past (see Section III), our system presents a novel application based on the well established fact that delay tolerance can be exploited in MANETs [9]. Future work includes determining how guaranteed unique content, such as email, impacts network performance. In addition, we plan to investigate the result of disruptive events on throughput and to analyze the security properties of the system.

Our **contributions** to existing literature include:

1) We demonstrate that MANETs can effectively distribute content at nation scale even when users are sparsely distributed, including unpopular content
2) We demonstrate that opportunistic encounters resulting from exploratory user movement are key to disseminating content in normally isolated topologies
3) We demonstrate that NSHoc is performant across multiple topologies, mobility models and content popularity distributions
4) We evaluate common caching strategies for MANETs at nation scale
5) A nation scale network simulator that models human mobility both between and within cities

II. BACKGROUND

A. *Nation Scale Topology*

Apps like MeshMe [16] and Jott [17] use point-to-point WiFi connections to build mesh networks so that users can chat even when their phone is in airplane mode or no WiFi network is available. But in a nation scale topology where only a limited number of cities have Internet access and the users are sparsely distributed, building mesh networks is not an option. Users may not encounter another user for hours at a time because of the sheer size of the topology. We assume only two users are ever connected to one another at a time. In the language of graph theory, the largest connected component we have is order two. We call this type of network a *normally isolated* network (see Figure 1). Since only a limited number of cities have Internet access, users in locations without Internet must rely on other users fetching content from Internet capable locations. This content must then be passed via opportunistic encounters back to the original requester.

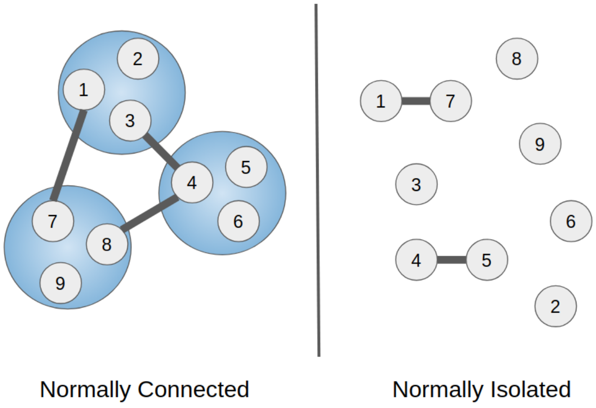

Figure 1: Topology Connectedness

B. *Human Mobility*

We modeled user movement both within a city and between cities. For movement within a city, we used Truncated Levy Walk (TLW). For movement between cities, we used the Exploration and Preferential Return Model (EPR).

User movement determines how often users will be within WiFi range of one another in order to exchange content. Common mobility models include Random Walk (RW), Gauss-Markov, Group Point Reference (GPR), Time Variant Group, Erdos-Renyi, and Model B [24] [12]. Each of these models is a variant of RW. Gauss-Markov is RW with a normally distributed step size. Group Point Reference breaks users into groups, where each group follows a RW leader. Time Variant Group integrates location popularity and group colocation on top of GPR. Erdos-Renyi is random traversal of a graph of locations. Model B is similar to GPR except that users can join or leave their group.

Truncated Levy Walk (TLW), on the other hand, is based upon traces of human and animal movement. Both Panisson [18] and Rhee [21] have argued that TLW is one of the best approximations of human mobility in a city currently available. The Levy Walk model requires two key parameters - flight length and pause time. Flight length is how far the agent moves each time step and pause time is how long the agent remains in each location.

Pappalardo et al. [19] proposed a model called the Exploration and Preferential Return Model (EPR) where agents are split into two groups, returners and explorers. Returners tend to return to a small subset of locations, whereas explorers have a higher likelihood to travel within a larger set of locations or to entirely new locations. This dichotomy of movement into returners and explorers provides an intuitive foundation for mobility models that describe how users move between cities.

III. RELATED WORK

Prior work differs in at least one of three ways: it was designed for a smaller topology, it requires a more connected network or it relies on existing infrastructure. The most closely related network paradigm to NSHoc is Rangzen [13], which focuses on content distribution at city scale, as opposed to nation scale, in the face of blackouts or censorship. Listen First, Broadcast Later (LFBL), proposed by Meisel et al. [15] was designed for a scenario where nodes can be in contact with multiple other nodes simultaneously and the time between node contacts is insignificant because the topology is small. In contrast, NSHoc operates in a nation scale scenario where only two nodes are ever in contact at a time. BlooGo [4] is similar to LFBL, except that it uses proximity information stored in a bloom filter as a heuristic for its forwarding algorithm. Otherwise, BlooGo was designed for a scenario similar to LFBL and differs from NSHoc in the same ways. Kite [25] is an NDN variant that supports mobile nodes on the perimeter of the network, but assumes that those nodes interact with a static infrastructure.

Prior MANET research was often conducted over small topologies like the one used by Guidec [10], which was 1 km x 1 km with only 120 hosts [14] [11] [26]. In some cases, such as Datta's paper on Autonomous Gossiping [6], the challenges presented by topology are not even discussed. Still other research, such as Chen's forwarding algorithm SPOON [5], assumes that users are in groups and connectivity is nearly constant among group members unless they move to another group. Other MANET related related research considers battlefield scenarios, but these systems fall short in all three categories by relying on existing infrastructure and operating over smaller, more connected topologies [23] [20] [8].

IV. SYSTEM DESIGN

In order to design a MANET based system for nation scale content distribution in normally isolated topologies, we had to address a number of technical challenges. We had to determine the best method for routing information and what caching policy would perform optimally in such a disconnected environment. Prior to addressing this question, we had to both understand and model human mobility at this scale (see Section II-B and Section V for details), which was a significant challenge. In addition, we had to generate content distributions and consider the best approach to addressing and packaging content.

NSHoc opportunistically broadcasts Interests and responses to Interests (web content) via ad hoc point-to-point connections between users' smartphones. These exchanges occur whenever users are within WiFi range of one another (100 meters). Fresh copies of content are fetched whenever a user enters a location with Internet access. When two users meet, they exchange content using a multitier caching policy and an efficient way to request and package content. Content spreads outward from Internet capable locations via these cache swaps between users.

Addressing and Caching Content

The Interest packet contains fields for content description and the time generated. The Data packet contains fields for content description, time generated, signature of content by trusted third party and the content itself. See Figure 2.

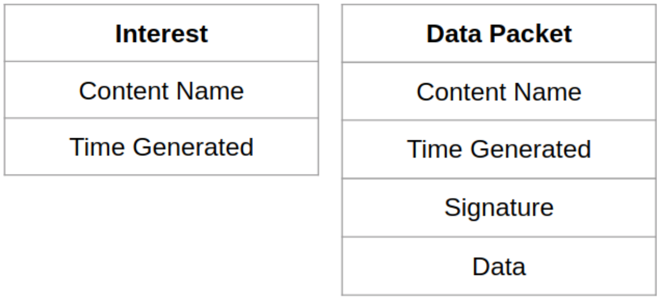

Figure 2: Format of Interest and Data Packets

Each user's mobile device holds a Global Interest Cache (GIC), User Specific Interest Cache (UIC) and a Content Store (CS). The GIC keeps a list of all Interests that have not been fulfilled, including those generated by the user. The GIC holds no information about where an Interest was originated because we assume there is no consistent topology, which helps with scalability because we only need to carry one copy of each Interest. The Data packet fulfilling an Interest propagates back to the original requester with no information about what path to take. The UIC contains all open Interests that the device user is waiting to have fulfilled. The CS contains requested data stored as a compressed file where each file holds all data necessary to fulfill an Interest.

Propagating Content

When two users meet in NSHoc, they exchange the contents of their CS and GIC. They copy the contents of the other user's CS and GIC into their own. If they already have a particular Interest or piece of content, they only copy it if it was generated more recently. The purpose of this exchange is both for the user to satisfy their own requests for content and to store content for other users in the network. Every single user in the network is acting as a cache for every other user. By also storing other users' Interests, they are able to prioritize that content when fetching from the Internet or exchanging content with other users in the event that they are forced to evict content from the CS due to space limitations.

If a user is able to satisfy any Interests in their UIC, the Interest is removed from their UIC. Likewise, if they receive content that satisfies an Interest in the GIC, it is removed from their GIC. See Figure 3 for an example of how this cache swap occurs.

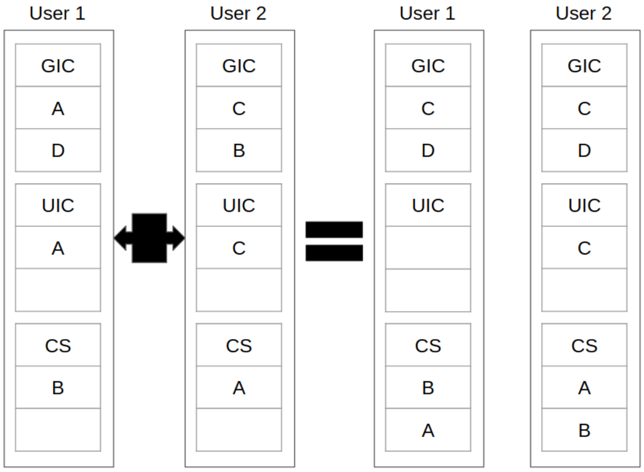

Figure 3: Example of Exchange Between Two Users and the Interaction Between the GIC, UIC and CS

If there is more content shared than can fit in a user's cache, they apply a two tier caching policy - Evict Oldest followed by Evict Least Recently Used (LRU). In other words, when there is not enough room in the cache they drop older content and if the content is the same age, drop the least recently used content. Ties are broken at random.

Fresh copies of content may also be fetched whenever users are in an Internet capable location. While in an Internet capable location, content for all Interests in the GIC and UIC is fetched from a trusted third party (TTP) that signs the content. If there is too much content to fit in the CS, the caching policy is once again applied.

Caching

When designing NSHoc we considered the following caching policies - evict random, evict oldest, evict least popular, evict least recently used and evict least recently requested. More details on the difference between the cache eviction policies and their impact on performance will be discussed in Section VI-E.

In addition to the caching policy, the CS also drops any content that is not considered fresh. The freshness window determines how fresh content must be in order to be considered valid. The freshness of the content can be calculated using the following equation:

$$freshness = current\_time - origination\_date$$

Security

We assume all content is signed by a trusted third party (TTP) when it is initially distributed at the Internet capable locations. One additional benefit of the TTP is that it can fetch content for users that they may not want their device to fetch directly. We acknowledge additional security concerns such as user privacy and denial of service attacks, among others, and we leave those questions for future work.

A. *NSHoc In Action*

Figure 4 shows how NSHoc allows a user in a normally isolated topology and with multiple degrees of separation from any other user that has visited an Internet capable location to receive their content via ubiquitous caching. The user, Jane, generates an Interest for content via a UI on her smartphone. Then, that Interest is propagated via opportunistic encounters to Bob, who fetches that content from the Internet. The content is then propagated via opportunistic encounters back to Jane, who receives an alert on her smartphone that she can now view the content. All of this happens without any of the users taking any action except Jane, who created the original Interest.

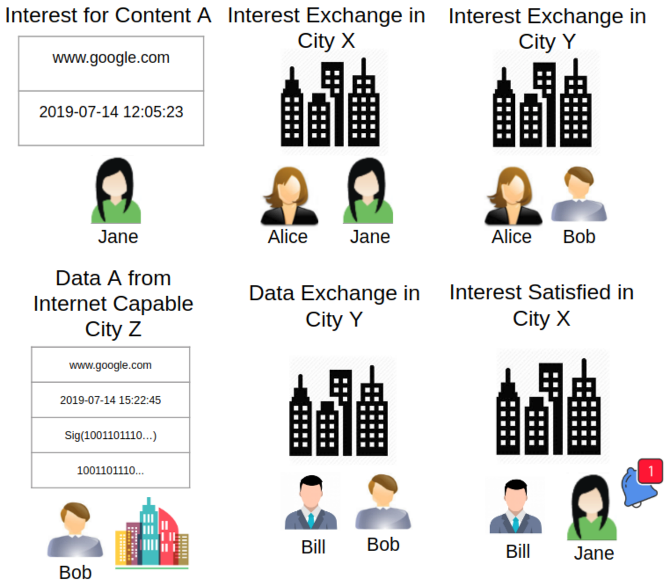

Figure 4: Jane receives requested content A even though she never visits an Internet capable location and is multiple degrees of separation from Bill, who delivers the content.

V. SIMULATION METHODOLOGY

To evaluate NSHoc, we created a custom simulator for human mobility at nation scale. First, we generated topologies for Puerto Rico and Syria. Second, we built a mobility model for user movement throughout such a topology using well established models. And third, we created a model for the size and distribution of web content.

We then used the topology, mobility model and web content information to build an event driven simulator written in Java. In the simulator, users move from city to city generating Interests, fetching content and exchanging Interests and content with other users. Using this simulator, we implemented NSHoc as described in Section IV.

A. *Topology*

We used two topologies in order to evaluate NSHoc - Puerto Rico and Syria. We chose these locations because they provide variability in topology size and city distribution - with Syria being larger and having a more sparse distribution of cities. To model each of these topologies, we needed a list of cities, the population of each city, the travel time between cities and a logical graph of the cities.

We used simplemaps to get a list of cities, lat/long coordinates and populations for Puerto Rico and Syria [3]. The list contained all cities in that nation with a population over 1000 people. We then used the Google Maps Distance Matrix API to collect drive times in between cities. The API could not process a few cities in each topology, so we removed them from the lists. The topology created for Puerto Rico had 143 cities (10153 routes) and Syria 216 cities (23220 routes).

We then used the travel times between cities to determine which cities were directly connected to one another by roads and create a logical graph of cities. This calculation was done using the following equation, where distance D is measured in miles and the goal is to determine if b is on the path from a to c: $|D_{ab} + D_{bc} - D_{ac}| <= threshold$. We used 1.86 miles as the threshold.

B. *User Mobility Model*

For user mobility, we had to develop two models. One for movement within a city and one for travel between cities. We needed to understand movement within a city to calculate the probability of two users meeting if they were in the same city for a given period of time. Movement between cities was used to compute arrive times and leave times for users within our simulation. We ignored any chance of content being exchanged while users are moving between cities because their interaction time would likely be too short for an exchange to occur, a decision which could only reduce performance. We developed a model to calculate the probability of two users meeting in a city of size X for time T. In other words, if two users are in a city of 20 square miles for 3 days, what are the chances that they will come within WiFi range of one another? Users are assumed to be sleeping ten hours each day, during which time no exchanges are able to occur.

To calculate the probability of two users meeting in a city of size X over time T, we used a python library developed by Panisson called PyMobility [18]. This library allowed us to simulate user movement according to the truncated levy walk mobility model with varied maximum pause lengths and flight times as described in Section II. The pause time maximum was set to eight hours (how long someone may be at work or asleep) and the flight length maximum was set to the width of the map (the length of the city) [21]. We ran repeated simulations over map sizes ranging from 1-100 square miles for a year in simulation time to determine how the chance of two users meeting changed with both city size and total time in the city. Using these results, we generated best fit lines for each city size that could be used in the simulator to determine the probability of two users meeting if in a city of size X for time T.

In order to use the results from PyMobility in the simulator, we needed to estimate the total square miles that each city's population center occupied within the topologies we had generated. Because no database containing this information for the cities we had selected existed (potentially due to how small many of them were), we used an interactive map with satellite data that allowed us to draw polygons on the map and then provided the total square miles contained within the polygon to gather this data [1]. We could then use the mobility model generated with PyMobility in the simulator.

User movement between cities required a different approach. As noted in section II, Pappalardo et al. [19] generated a model called the Exploration and Preferential Return Model (EPR) that divides agents into returners and explorers. Returners tend to return to a small subset of locations, whereas explorers have a higher likelihood to travel within a larger set of locations or to entirely new locations. For the purposes of analyzing NSHoc, we used five models [24] [12]. None of these models are intended to be a perfect match of real world conditions, but rather to show that NSHoc is robust under diverse conditions (see section VI-B).

1) Random Walk - randomly traverses the map
2) Returner - has a home city, favorite locations and small chance of exploring new areas
3) Returner Explorer – the Returner Model where K percentage of users have a higher rate of exploring cities outside their favorite locations
4) Social Returner - the Returner model with Social Groups
5) Social Returner Explorer - the Social Returner Model with Exploration

C. Content

For the purposes of the simulation, we used the Alexa Top 1000 websites to model content. To generate Interests for content we needed a content popularity distribution. We also wanted to have a rough idea of the size of compressed content to demonstrate that it would be realistic to cache the amount of content required for NSHoc to store content on a mobile device.

For the content popularity distribution, we used a distribution based upon the popularity of the Alexa Top 1000, though we also include a uniform distribution and a distribution weighted heavily towards the top fifty pieces of content for comparison (see Section VI-D). The popularity distribution for the Alexa Top 1000 was obtained using the Page Views Per Million for each day averaged over one month (March, 2018) from the Alexa Web Information Service. Each user in the simulation then drew from the inverse CDF of this distribution to generate new Interests every 4 hours of simulation time.

To gain a better idea of the size of website content, we used results from an analysis of the Alexa Top 1000 on httparchive [2]. According to this data, the Alexa Top 1000 has an average content size of approximately 3700 KB. Therefore, it would require about 800 MB to store 200 pieces of content or 1600 MB for 400 pieces of content. Since the analysis of NSHoc will be performed with the Alexa Top 1000, these numbers represent 20 percent and 40 percent of world content respectively.

VI. RESULTS

In all graphs, 'Fraction Fulfilled' is the total percentage of a user's Interests fulfilled by the end of the simulation, which simulated 1 month of activity. For a majority of the simulations, we used the Social Returner Explorer,or *SRE*, model because it takes into account both the social and tempo-spatial properties of human movement and we believe it to be the most representative of actual human movement at nation scale. However, as we show in Section VI-B, our system is performant across a variety of mobility models.

In SRE, there are social groups with Internet capable cities in their group, *ICGs*, and those without Internet capable cities, *NICGs*. All groups have a set of favorite locations and NICGs have no Internet capable cities in their favorite locations. The fact that our system is performant for NICGs shows that it is truly disseminating content via opportunistic encounters and ubiquitous caching rather than simply fetching content from the Internet.

In Section I we made the following claims regarding NSHoc:

1) We demonstrate that MANETs can effectively distribute content at nation scale even when users are sparsely distributed, including unpopular content
2) We demonstrate that opportunistic encounters resulting from exploratory user movement are key to disseminating content in normally isolated topologies
3) We demonstrate that NSHoc is performant across multiple topologies, mobility models and content popularity distributions
4) We evaluate common caching strategies for MANETs at nation scale

Claims 1 and 3 are substantiated by demonstrating that NSHoc is performant across a variety of topologies, mobility models and content distributions. We show that even the least popular content, which may suffer with less users, can be delivered with very high success rates by increasing the number of users within reasonable bounds (Section VI-C).

Claim 2 is substantiated by Section VI-B. In Section VI-B we show that the mobility model which combines both exploratory behavior and social group dynamics, the Social Returner Explorer, or SRE, model is most performant. The exploratory behavior results in opportunistic contacts between social groups that are beneficial to system performance and expected according to prior research (See Section II-B).

Claim 4 is substantiated by Section VI-E, where we evaluate multiple caching policies and explain our rational behind choosing a particular multitier policy for NSHoc.

A. Comparing Topologies

We begin by comparing system performance in Puerto Rico and Syria with 10 thousand users, 10 internet capable cities, a freshness window of 3 days and a cache capable of holding 300 of 1000 pieces of content. Figure 5 below shows system performance for ICGs and Figure 6 shows system performance for NICGs. For ICGs, over 97% of Interests are fulfilled for 90% of users in both Syria and Puerto Rico. For NICGs, Puerto Rico still achieves this same performance while Syria drops to 87% of Interests for 90% of users. This drop from ICGs to NICGs in Syria is due to the fact that Syria is both larger and more spread out than Puerto Rico, so it takes longer for content to disseminate from Internet cities to the rest of the topology.

Figure 7 shows the performance of NSHoc for the 100 least popular pieces of content. For Puerto Rico, over 90% of users receive all requested unpopular content. In Syria, that number is reduced to 80% because the topology is larger. Section VI-C shows that the percentage of Interests for unpopular content fulfilled grows proportionately to the number of users.

The throughput in this scenario is .42 pieces of content per second in Puerto Rico and .4 pieces of content per second in Syria. These values were calculated by dividing the total number of fulfilled Interests by the number of seconds over which the simulation ran. Both ICGs and NICGs were included in the calculation.

Due to space constraints, we could not include graphs for time to satisfy. For NICGs, users in both Puerto Rico and Syria fulfill 40% of Interests from their own cache, but for Puerto Rico 80% of Interests satisfied are fulfilled in less than one day as opposed to only 60% in Syria. In contrast, ICGs in both topologies received 80% of their content in less than a day. These results show both the power of ubiquitous caching and that topology size is significant chiefly for those groups without Internet capable locations because the content must propagate out to reach them. Among all users, Interests were satisfied within five hours on average.

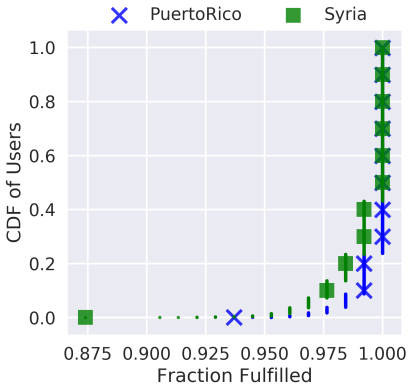

Figure 5: ICGs: Puerto Rico and Syria

B. Comparing Mobility Models

Now we compare the mobility models described in Section V in Puerto Rico with 10 thousand users, 10 internet capable cities and a cache capable of holding 300 of 1000 pieces of content. Figure 8 shows Interests fulfilled for each mobility type. From this graph it is apparent both that Random Walk (RW) and Social Returner Explorer (SRE) are the most performant. The reason RW performs well is that users explore the topology in a uniform fashion, which helps move content throughout the network. Social Returner (SR) and Returner (R) restrict users to a subset of locations, thereby reducing the ability for content to proliferate because users are less mobile. Returner Explorer (RE) allows a subset X of users to traverse the map while restricting the rest. If this subset is increased, the behavior of of RE will approximate RW.

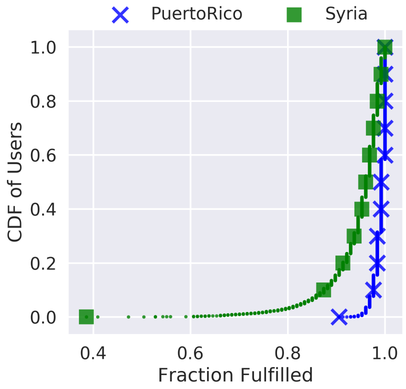

Figure 6: NICGs: Puerto Rico and Syria

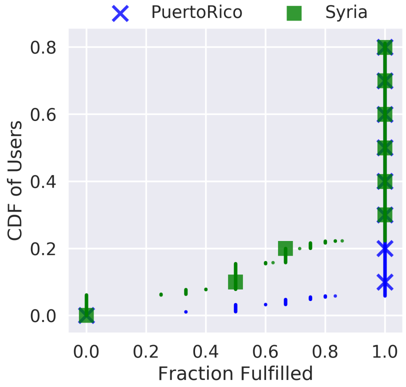

Figure 7: NICGs: Puerto Rico and Syria - 100 Least Popular

SRE is the most performant because it contains colocated social groups and explorers who traverse the topology. The explorers help disseminate content between groups and users within social groups have a high probability of meeting. Figure 9 shows Interests fulfilled for NICGs in both SR and SRE. 30% of the users in each group are explorers in SRE for this simulation. These results show that it is not necessary for all users to explore the topology, such as in RW, but that it is enough for a subset of users to demonstrate exploratory behavior. They also show that exploratory behavior is a requirement of NSHoc. The significant takeaway from these results are that NSHoc is performant for any mobility model that contains sufficient exploration of the topology.

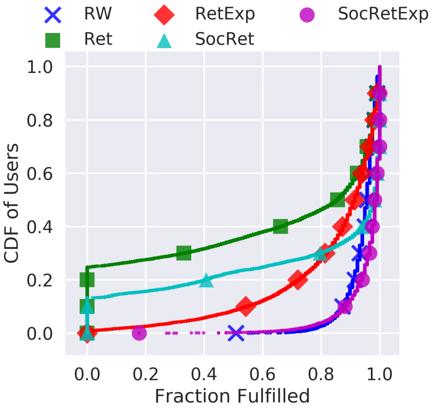

Figure 8: All Users: Mobility Model

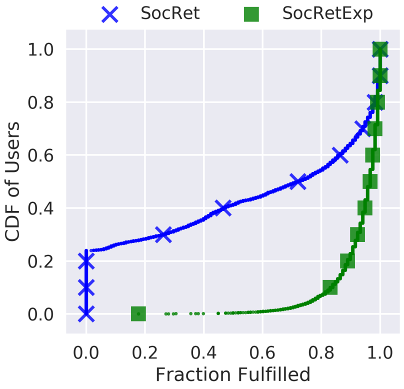

Figure 9: NICGs: Mobility Model - SRE and SR

C. Number of Users

First, we evaluate system performance as the number of users is varied in Syria with 10 Internet capable cities, a cache capable of holding 200 of 1000 pieces of content and a freshness window of 1 day. We are intentionally using less Internet capable cities and a tight freshness window to show the impact of increasing users. To show the impact of the number of users even more clearly, we consider success rates for the least 100 unpopular pieces of content to NICGs. Figure 10 shows that with 10 thousand agents over half of users are receiving less than 55% of their desired content. By increasing the number of users to 200K, over 90% of users are receiving over 90% of their desired content. Keep in mind that mesh network apps such as Jott [17] had over half-a-million users as of 2015, so 200K is within reasonable bounds. As user density increases, NSHoc continues to show improved performance because it is driven by point-to-point meetings between individual users.

D. Content Popularity Distribution

Next, we evaluate system performance as the content popularity distribution is varied in Puerto Rico with 10 thousand users, 10 internet capable cities and a cache capable of holding 200 of 1000 pieces of content. Three potential distributions were considered - uniform content popularity, a distribution based upon the Alexa Top 1K as described in section V-C, and a distribution weighted heavily towards to top 50 pieces of content. As can be seen in Figure 11, all distributions fulfilled over 90% of Interests for over 80% of users, showing that NSHoc is able to function across a range of distributions. Skewed distributions are more performant because it requires less cache space if there is less popular content, but NSHoc works well even with a uniform random distribution.

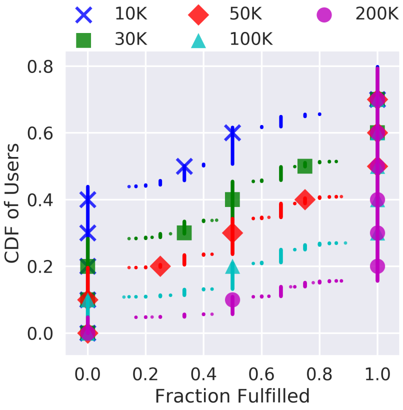

Figure 10: NICGs: Number of Users - 100 Least Popular

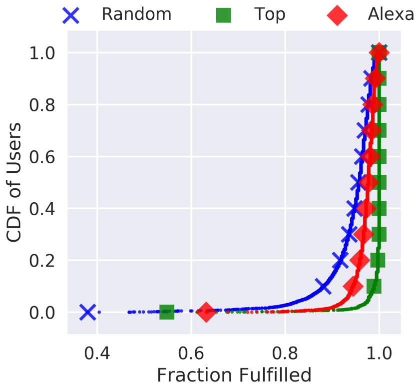

Figure 11: NICGs: Content Popularity Distribution

E. Caching Policy

First we compare the available caching policies as described in Section IV in Syria with the 10 thousand users, 20 internet capable cities and a cache capable of holding 200 of 1000 pieces of content. We chose Syria because as the largest topology it most clearly demonstrates the difference in performance between the policies. In these graphs, 'Ideal' is the case where the cache can hold all 1000 pieces of available content.

Looking at Figure 12, we see that Least Recently Used (LRU), Oldest and Least Recently Requested (LRR) are the closest to the ideal case. Data showed that LRR and LRU require less time to satisfy Interests than Oldest. However, as Figure 13 shows, for unpopular content Oldest is far more performant than both LRR and LRU.

To balance these trade-offs, we chose a two stage policy that uses Oldest as the primary and LRU as the secondary policy to break ties. This two stage policy provides the benefit of satisfying unpopular content while settling ties in a way that aids response time. Space prevents inclusion of the graphs for this policy.

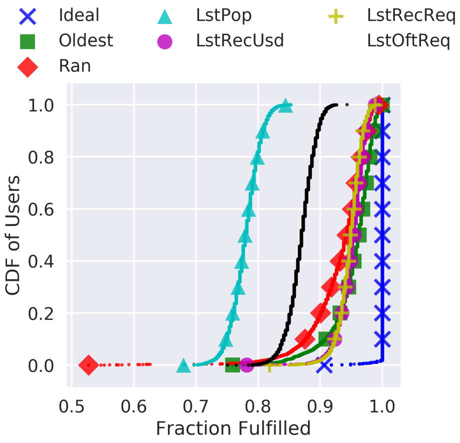

Figure 12: NICGs: Cache Policy

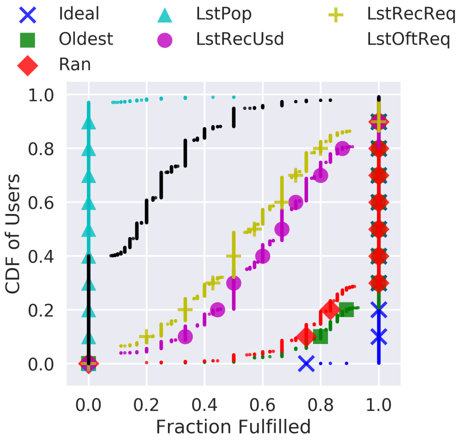

Figure 13: NICGs: Cache Policy - 100 Least Popular

VII. SUMMARY AND FUTURE WORK

In this paper, we showed that mobile ad hoc networks can be used to distribute content at nation scale even when users are sparsely distributed. We presented NSHoc, which enables smartphone users to request and receive content via opportunistic encounters, and showed that it can effectively distribute content at nation scale. Our system is performant even for unpopular content and across a variety of topologies, mobility models and content distributions. NSHoc demonstrates that MANETs are an attractive alternative for distributing content at nation scale in the face of infrastructure loss. Future work includes determining how guaranteed unique content, such as email, impacts network performance and studying how disruptive events alter throughput.

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