Empowering Women Microentrepreneurs through Non-Terrestrial Networks

**Navrati Saxena1, Abhishek Roy2, Melody Moh1, Sree Hari Karri1**

**1Dept. of Computer Science, San Jose State University**

**2Advanced Communication and Technology, MediaTek Inc.**

**{navrati.saxena, melody.moh, sreehari.karri}@sjsu.edu, Abhishek.Roy@mediatek.com**

# **Abstract**

According to African Development Bank, nearly 26% of women in African countries are either starting or managing a business. Most of these businesses are highly localized and cater to niche products and services. These women microentrepreneurs require network connectivity to help them start or expand on their business which is crucial to local economies. Since setting up mobile network infrastructure is not feasible in very remote regions, we propose an innovative application of Non-Terrestrial Networks (NTNs) to enhance internet connectivity. We perform user capacity planning by simulating operations performed by a women microentrepreneur and establish data usage benchmarks using custom built applications. We propose a model that can significantly expand online access for these entrepreneurs. The findings demonstrate the potential of NR-NTNs and IoT-NTNs, having the capacity to provide services to 2666 and 238 simultaneous users respectively. The improved connectivity and cost-effective internet service will foster economic growth and gender equity in the digital world.

***Keywords***: Women Microentrepreneurs, Network Connectivity, Non-Terrestrial Networks (NTNs), User Capacity Planning, Economic Growth and Gender Equity

# Introduction

Micro-entrepreneurship is an approach to entrepreneurship that emphasizes the creation of small businesses designed to meet the needs of a specific market niche or community. Micro-entrepreneurs often operate in industries that are underserved by larger businesses or that require specialized knowledge or skills. On June 27, the Department of State joins the global community in recognizing Micro, Small, and Medium-sized Enterprises (MSMEs) Day by celebrating the contributions of women-owned MSMEs to the global economy. Women micro-entrepreneurs are a growing market force, serving as a critical source of innovation and job creation and fueling economic growth. Unfortunately, women-micro-entrepreneurs do not have equal access to the capital or the networks. The COVID-19 pandemic exacerbated these social and economic inequities, leaving devastating and disproportionate impacts on women micro-entrepreneurs. A recent survey of women entrepreneurs in low-and middle-income countries, more than 80% of respondents indicated the pandemic has negatively impacted their business, and nearly 40% had to close their business. Recent research from the World Bank [1] found that women-owned businesses were nearly six percent more likely to close during the pandemic compared to those owned by male counterparts.

Mobile connectivity and coverage at an affordable price are identified as major steps towards the development and progress of women micro-entrepreneurs [2]. However, the affordability of a suitable mobile connectivity in Low- and Medium-Income Countries (LMIC) is a big challenge. In this paper we explore Non-Terrestrial Networks (NTN) to solve this coverage and connectivity problem. We also point out how low-cost cellular Internet of Things (IoT) can be integrated with NTN to provide connectivity at a cheaper rate, affordable to women micro-entrepreneurs even in LMIC.

In section II we propose a new connectivity and traffic model for women micro-entrepreneurs and estimate the traffic requirements of a single women micro-entrepreneur. The section details the architecture of the testing application and the framework used to simulate low-bandwidth network conditions. We discuss the major channel model for 5G NTN and IoT-NTN in Section III. Using these channel models, in Section IV, we propose an innovative method to solve the connectivity problem of women micro-entrepreneurs at an affordable cost. We also point out the scalability, low risk-factor and financial sustainability of our solutions. Societal impacts and inclusiveness are highlighted in Section V. Finally, Section V1 concludes.

# novel connectivity model for women micro entrepreneurs

The major innovation in our proposal lies in estimating NTN satellites’ user capacity based on supported throughput. Our throughput calculation is based on cellular broadband and IoT system, as our primary objective is to provide a complementary network of cellular systems for women micro-entrepreneurs [1]. Throughput per session, i.e., the minimum throughput required for maintaining the service [1] is obtained by:

where Rate (Kbps) refers to application layer data rate, duration refers to average service duration of each service, Duty Ratio refers to ratio of data sent per session, and BLER refers to block error rate allowed in every session.

Analyzing the trends and necessity of women micro-entrepreneurs, especially in developing countries, we find that the major services used by women micro-entrepreneurs are voice calls, web browsing (HTTP), email, file transfer (FTP) and in-frequent video calls. To ensure efficiency, we built a react-native application and optimized for bandwidth to perform the tests.

## Testing Framework

React Native is an open-source framework on which native applications i.e., applications that can work on both Android and iOS platforms can be built. We chose React Native for our UI since it allows for rapid development and provides more room for network optimization compared to other major frameworks, like Xamarin, Cordova, Ionic or Flutter.

For real-time communication, we built our features based on the open-sourced WebRTC protocol **[?]**. WebRTC stands for Web Real-Time Communication, and it is a specification that enables exchange of text, audio, video, and data in general over APIs. It provides for supports web browsers, mobile devices, and native clients. We use firebase for implementing our signaling and STUN (Session Traversal Utilities for NAT) /TURN (Traversal Using Relays around NAT) servers **[?]**. The signaling server is used to maintain a connection between two communicating devices. The TURN/STUN servers are used to exchange metadata and establish connection if the peer-to-peer connection fails due to firewall or NAT restrictions.

For the back end, we use the Backend-as-a-Service (BaaS) called Firebase **[?]**. We use these services to authenticate users, store user data, messages, videos, and any files sent over chat. We use the Cloud Firestore database **[?]**, as it keeps data in sync across client applications using real-time listeners and supports offline features. This allowed us to build a responsive application that is eventually consistent and ensures messages get delivered even when network availability is low.

The React Native Firebase SDK is used to integrate the application with the Firebase Cloud. This allows for each component to scale and be update independently. Figure 1 shows the application architecture and how React Native, WebRTC, and Firebase work together to provide an efficient yet flexible framework for delivering a bandwidth-optimized application. In the next section we elaborate on the different testing methods and analyze usage data for various applications.

A diagram of a computer network

Description automatically generated

Figure 1: Application and WebRTC architecture

## Bandwidth Testing

To evaluate the performance of our application under different network conditions, we used an iPhone 15 pro and OnePlus 6T devices. The two devices were used to communicate with each other testing the various features such as chat, video call, file transfer and emails to establish benchmarks. The network emulation tool in Android Developer options and Network Speed Manager app were used to simulate different uplink and downlink rates during testing.

The manual setting enabled us to test for speeds as low as 100Kbps and evaluate the performance of the application. It worked by establishing a VPN and setting the uplink and downlink speeds to whatever bandwidth we wanted to simulate. This allowed us to accurately measure the lowest possible bandwidth that allowed the application to work seamlessly without any loss of data.

Web browsing was tested using the Opera browser **[?]** which is custom-built for ultra-low bandwidth usage. Gmail was used to test the bandwidth used by emails. All applications individual data consumption was measured using the My Data Manager application.

Our custom application consumed 22-38% lesser data than applications like Facebook messenger and Telegram. These gains can have major implications for rural regions and under-developed communities with sparse network infrastructure. Users in these kinds of regions are generally required to travel a certain distance to find a “hello point”, which is a specific region where mobile network can be found in a remote area. Users in such areas very rarely get to use internet since obtaining basic call level signal is a task. By optimizing data usage, our custom application enables more reliable and affordable remote communication under real-world connectivity restrictions. We achieved efficiency gains without compromising on performance of call quality, video frame rate and file transfer speeds.

Our novel estimation results for uplink and downlink throughput per session are provided below in Table 1 and Table 2.

Table 1: Uplink Throughput per Session

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Traffic Params. | Uplink | | | | Tput per session (kb) |
| Rate  (kbps) | Duration  (seconds) | Duty Ratio | BLER (%) |
| Text Chat | 100 | 300 | 0.007 | 1% | 207 |
| VoIP | 100 | 300 | 0.032 | 1% | 980 |
| Video Call | 100 | 300 | 0.14 | 1% | 4,521 |
| HTTP | 100 | 300 | 0.025 | 1% | 770 |
| Email | 100 | 300 | 0.237 | 1% | 7,200 |
| FTP | 100 | 300 | 0.001 | 1% | 20 |
| App Download | 100 | 300 | 0.004 | 1% | 138 |

Table : Downlink Throughput per Session

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Traffic Params. | Downlink | | | | Tput per session (kb) |
| Rate  (kbps) | Duration  (seconds) | Duty Ratio | BLER (%) |
| Text Chat | 100 | 300 | 0.007 | 1% | 207 |
| VoIP | 100 | 300 | 0.032 | 1% | 980 |
| Video Call | 100 | 300 | 0.14 | 1% | 4,521 |
| HTTP | 100 | 300 | 0.228 | 1% | 6,930 |
| Email | 100 | 300 | 0.019 | 1% | 590 |
| FTP | 100 | 300 | 0.059 | 1% | 1,780 |
| App Download | 100 | 300 | 0.366 | 1% | 11,118 |

Each women micro-entrepreneur in the network has a range of throughput values resulting from services accessed during peak hours. Hence, the calculation of throughput requirement of a single women micro-entrepreneur () [8, 9] is obtained from the equation below:

where *ρ* is the traffic penetration ratio, i.e., the proportion of the service used by women micro-entrepreneurs in a region, BHSA denotes busy hour service attempt, *PAR* is Peak to Average Ratio, which takes care of network overload, resulting from sudden traffic bursts.

Table 3: Traffic Model Parameters

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Traffic Params. | Urban | | Suburban | | Rural | |
| *ρ* | *BHSA* | *ρ* | *BHSA* | *ρ* | *BHSA* |
| Text Chat | 1.0 | 1.4 | 1.0 | 1.2 | 1.0 | 1 |
| VoIP | 1.0 | 1.3 | 0.5 | 1.0 | 0.5 | 0.9 |
| Video Call | 0.20 | 0.16 | 0.10 | 0.1 | 0.1 | 0.05 |
| HTTP | 1.0 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 |
| Email | 0.1 | 0.3 | 0.1 | 0.2 | 0.05 | 0.1 |
| FTP | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| App Download | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

Using the above equation, with the parameter values, provided in Table 3, and a penetration ratio of 20% for urban, 10% for suburban and negligible for rural areas, we estimate the throughput requirement of a single women micro-entrepreneur. Table 4 shows the new estimated throughput requirement.

Table : A Single Women Micro-Entrepreneur’s Throughput Requirements

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Traffic Params. | Urban | | Suburban | | Rural | |
| UL | DL | UL | DL | UL | DL |
| Text Chat | 348 | 348 | 273 | 273 | 207 | 207 |
| VoIP | 1,529 | 1,529 | 539 | 539 | 441 | 441 |
| Video Call | 145 | 145 | 50 | 50 | 23 | 23 |
| HTTP | 370 | 3326 | 102 | 915 | 46 | 416 |
| Email | 259 | 22 | 158 | 13 | 36 | 189 |
| FTP | 1 | 86 | 1 | 78 | 1 | 71 |
| App Download | 1.7 | 134 | 1.5 | 122 | 1.4 | 111 |
|  | 0.99 | 1.55 | 0.3 | 0.55 | 0.21 | 0.41 |

# Analyze NTN link budget and throughput

Link budget is a way to calculate all parameters in signal transmission from transmitter to receiver. There are many parameters calculated in link budget starting from transmit power, gain, loss, attenuation, noise, receiver gain [4], etc. In order to estimate the throughput, relevant parameters need to be calculated accurately as mentioned below:

### Effective Isotropic Radiated Power (EIRP): EIRP is a combination of transmitter power and antenna gain which transmitted uniformly in all directions. Mathematically, EIRP can be formulated using antenna transmit power PTX, cable loss LC, and transmit antenna gain GTX as:

*EIRP = PTX – LC + GTX*

### Figure of merit (G/T ratio): G/T is an important parameter in link budget. It is used to specify system performance. The formula of G/T ratio can be expressed as:

*G/T = Gainantenna – T Noise*

where *TNoise* represents the system noise temperature.

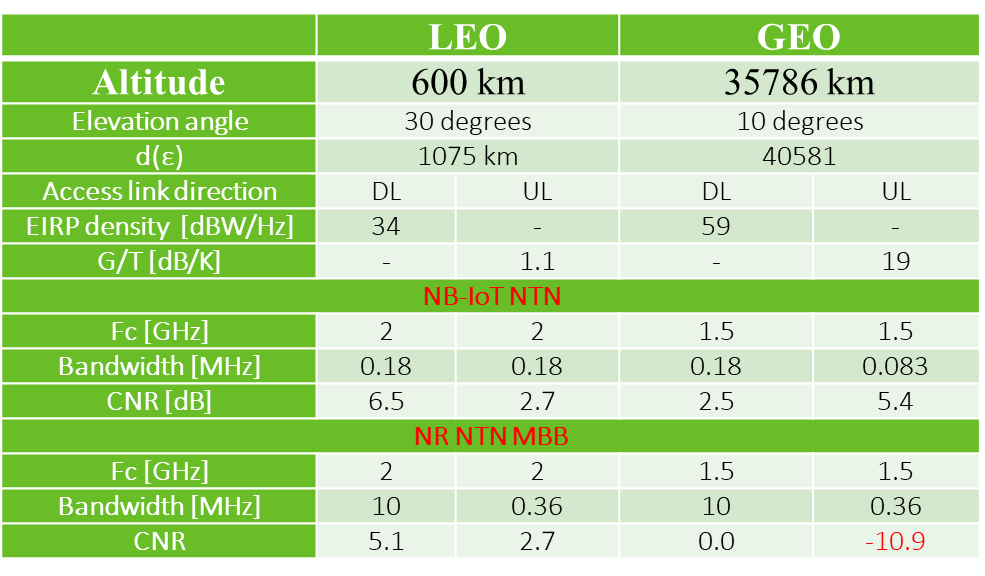
### Carrier to noise ratio (CNR): CNR represnts the ratio of carrier power to noise density. This is represneted as:

*CNR =EIRP +𝐺 ∕𝑇 −𝑘 −𝑃𝐿tot −𝐵*

where *k = -228.6* is the Boltzmann Constant, *B* represnts the channel bandiwdth and *𝑃𝐿tot* is the total pathloss including, free space loss, atmospheric path loss, shadowing margin, scintillating loss and any additional loss. Using these equations,

the estimated link budget for NR-NTN and IoT-NTN are shown in Table 5.

Table : Sample LEO satellite Link Budget



Using these link budget values for NR-NTN and IoT-NTN, in the next section, we will estimate the corresponding cell throughput and user capacity per cell.

# SATISFYING CONNECTIVITY OF WOMEN MICRO-ENTREPRENEURS

We perform dynamic system simulation based on the latest developments from 3GPP NR-NTN studies [4][5] by considering both S-band and Ka-bands, mentioned below:

* S-band: DL and UL carrier frequencies at 2 GHz, system bandwidth of 30 MHz, subcarrier spacing is 15 kHz.
* Ka band: DL and UL carrier frequencies at 20 GHz and 30 GHz, respectively, system bandwidth of 400 MHz, and the subcarrier spacing of 60 kHz.

## NR-NTN Solution: Scalability

Figure 2: NR-NTN Cell Throughput

For 3GPP NR-NTN systems [7][8] with LEO satellite at 600 kms orbital height, using parameters mentioned in Table 5, Figure 2 shows the average cell throughput for S-band and Ka-bands. For the S band, the average downlink and uplink cell throughput converges to about 15.6 Mbps and 5.6 Mbps respectively. For the Ka band, the average downlink and uplink cell throughput is about 190 Mbps and 200 Mbps.

Figure 3: Supported Women Micro-entrepreneurs by NR-NTN

Using these cell throughput results, a single women micro-entrepreneur’s requirement, mentioned in Table 4, and assuming only 10% of the cell throughput is allocated to women micro-entrepreneurs, we estimate the number of simultaneous active women micro-entrepreneurs, a single NTN cell can support. Figure 3 shows such a capacity of NR-NTN to support connectivity of women micro-entrepreneurs. The figure delineates that even with only 10% cell throughput allocated for women micro-entrepreneurs, the S-band itself can support 565, 1866 and 2666 simultaneous active women micro-entrepreneurs in urban, suburban and rural areas respectively. The capacity of Ka-band is more than 10 times higher than the capacity of S-band.

## IoT-NTN Solution:Low Risk and Finacial Sustainability

While NR-NTN is very promising solution to support high connectivity and throughput requirements of women micro-entrepreneurs, it depends on availability of future LEO satellites. Until the introduction of NR-NTN in recent future, a viable solution to provide connectivity to the women micro-entrepreneurs lie in to using readily available legacy cellular IoT (NB-IoT) over existing GEO NTN.

Figure 4: Supported Women Micro-entrepreneurs by IoT-NTN

Our new system-level simulation using IoT-NTN parameters, mentioned in Table 5, has achieved a downlink and uplink throughput of 1.5 Mbps and 500 Kbps. Using a similar approach and similar assumptions, we can estimate the number of women micro-entrepreneurs supported. Figure 4 delineates that even cheap IoT-NTN, which uses legacy GEO NTN and cellular IoT-technology, can provide required throughput support for 50, 166 and 238 simultaneous connections for women micro-entrepreneurs.

This connectivity solution using IoT-NTN incurs low ***Risk Level***, as the solutions are standardized and commercially available. For example, MediaTek is the lead-rapporteur in 3GPP IoT-NTN standards and MediaTek’s MT6825 is the world’s first commercial IoT-NTN chipset. Interestingly, most of the available IoT data plans are much cheaper than corresponding 3G/4G/5G cellular subscription charges. For example, there exists cellular IoT monthly data plans of only $3, $6 and $9 respectively for 1 MB, 50 MB and 100 MB data. In developing countries, with lower operating expenditure, this subscription cost could be further reduced. This low subscription charge will encourage women micro-entrepreneurs to use IoT-NTN coverage, thus providing the much-needed affordability and ***Financial*** ***Sustainability***. Over time we will analyze the dynamics of this financial sustainability across different developing countries.

# societial impacts and inclusiveness

GSMA’s “The Mobile Gender Gap Report 2022” [2] has pointed out that unfortunately the progress in closing the gender gap in mobile internet use is getting slow and stalled. Although smartphones have been the key driver of mobile internet adoption, the gender gap in ownership has widened in the last couple of years, with South Asia being the widest gender gap in mobile internet usage. Resolving this mobile gender gap requires a focus on improving handset affordability and digital skills.

Overall, NTN envisions to reduce the *digital divide* by increasing the coverage and connectivity. In the previous section, we have pointed out how our NR-NTN and IoT-NTN solutions will enable women microentrepreneurs’ access to the digital technology to increase their small business and services. This will also increase the Internet accessibility at and affordable cost, thereby reducing the digital divide and gender gap, mentioned in GSMA’s “The Mobile Gender Gap Report 2022”. Thus, from ***societal aspects***, our solutions will be ***inclusive*** to empower women micro-entrepreneurs in starting, managing and growing their small business and services. We plan to capture and analyze the effects of these inclusive solution a yearly basis.

# conclusion

In this work we provide a detailed description on exploring Non-Terrestrial Networks (NTNs) and Internet of Things (IoT) to provide an affordable internet service to women micro-entrepreneurs, particularly in LMIC and developing countries. WebRTC protocol was used to implement the low bandwidth application supporting multiple concurrent users without data loss and frame drops. Our approach demonstrated how effective NR-NTNs and IoT-NTNs by being able to support up to 2666 and 240 simultaneous users respectively. Our solution is also scalable and involves low risks. From the perspective of social impacts, it is also inclusive and provides financial sustainability, while having significant social impacts among women micro-entrepreneurs. Future efforts will focus on further optimizations to the application and having NR-NTNs implemented in remote and underserved regions.

##### Acknowledgement

##### References

1. M. Goldstein, P. G. Martinez, S. Papinei and J. Wimpey, “The Global State of Small Business during COVID-19: Gender Inequalities”, *World Bank Report, 2020.*
2. “Empowering Women Micro-Entrepreneurs through Mobile”, *GSMA Report.*
3. M. A. Arifin and N. M. N. Khamsah, “A Case Study in U. Capacity Planning for Low Earth Orbit Communication Satellite,” *IEEE Intl. Conference on Aerospace Electronics and Remote Sensing Technology*, 2018.
4. M. Conti, A. Guidotti, C. Amatetti, and A. V. Coralli, NB-IoT over Non-Terrestrial Networks: Link Budget Analysis, *IEEE Global Communications Conference (GlobeCom) 2020.*
5. A. Guidotti, C. Amatetti, A. V. Coralli, A. Mengali and S. Cioni, “Non-Terrestrial Networks: Link Budget Analysis”, *IEEE International Conference on Communications (ICC), 2020.*
6. F. Rinaldi et. al, “ Non-Terrestrial Networks in 5G & Beyond: A Survey”, *IEEE Access, Vol. 8, pp. 165178 – 165200, 2020.*
7. 3GPP TR 38.821, “Solutions for NR to support Non-Terrestrial Networks”, *Technical Report.*
8. 3GPP TR 38.311, “Study on New Radio (NR) to support non-terrestrial networks”, *Technical Report*.