# Research on

# Evolutional Integrated Satellite-Terrestrial Network (ISTN)

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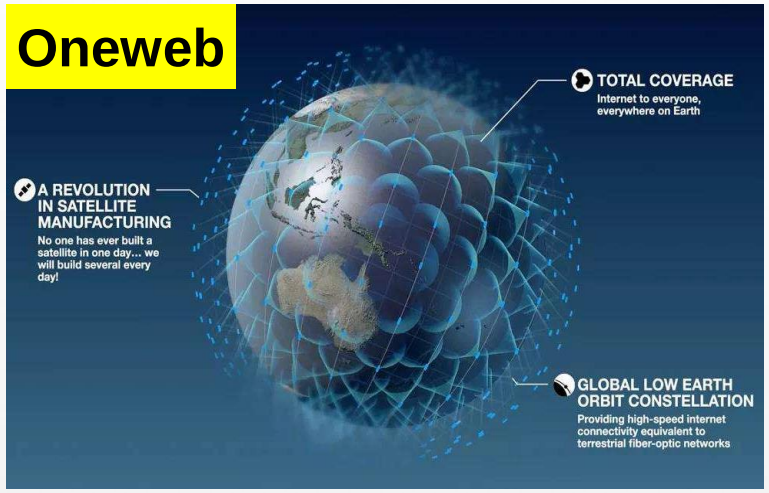
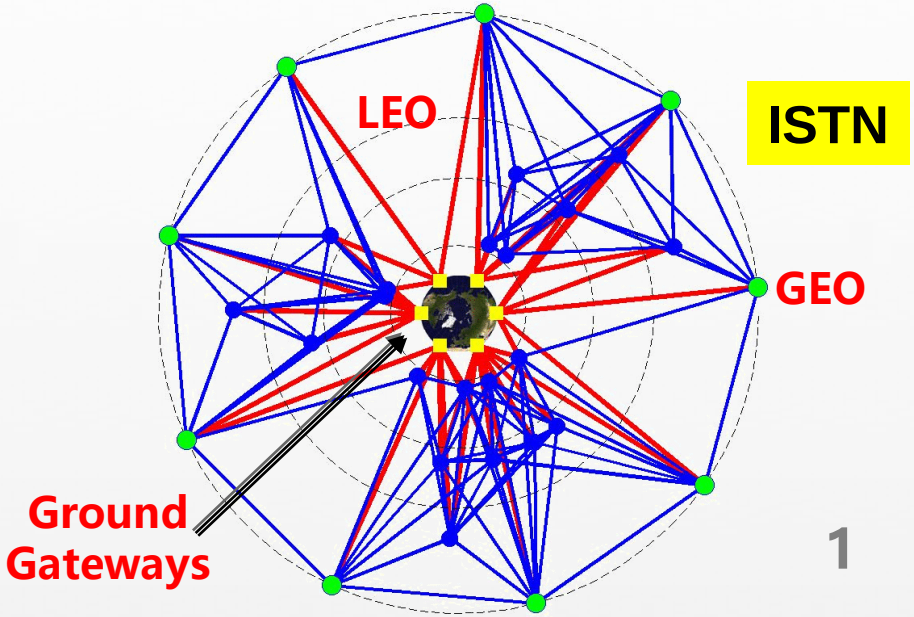
# ISTN is coming …

- Providing global Internet access from sky (Satellite) has made a huge comeback in recent years.
- Building Integrated Satellite-Terrestrial Network (ISTN) and/or Satellite Internet has become attractive and emergency more and more.
  - Consists of heterogeneous space nodes including Geostationary Orbit (GEO), Medium Earth Orbit (MEO), Low Earth Orbit (LEO) satellites and Ground Gateways.

# ISTN is still all IP, but different challenge …

- The goal of ISTN is to provide global seamless, ubiquitous services of accessing to Internet, is all networks(Satellite Network, 5G/6G, Internet…) together, which leading ISTN would still persist all IP architecture.

- Different from traditional satellite networks, ISTN based on the modern satellite networks, using huge number of satellites, which mean network connection would be always exist not like DTN, while the network connection would be always changing constantly not like terrestrial networks.

# New challenge from ISTN just begin …

- ISTN introduces many new issues:
  - Frequent changes of spatial network connection due to the satellites continual movement, which would decrease routing convergence performance of IGP and BGP, moreover, such kind of dynamic time-varying spatial network topology would kill the performance of higher level protocols at the same time.
  - Frequent changes (about 20 minutes) of access router (satellite) for LEO users and servers, which bring new mobility storms and problems.
  - Large RTT and loss rate due to long transmission distance, which also kill the performance of today's transport protocols.
  - New requirement for Security, Qos, Traffic Engineering, Management ...

# It is time to start …

- To investigate the future Application Scenarios and Network Structures of ISTN
- To test the performance of Internet protocols in ISTN especially on Routing and Transport area.
- To explore the unknown problems and challenges while integrating satellite networks and terrestrial networks.
- To study Protocols optimization for convergence of satellite networks and terrestrial networks
- To research on more new and effective addressing, routing, transport, and etc. solutions for future ISTN.

**Thanks!!!**
**Any comment are welcome!**

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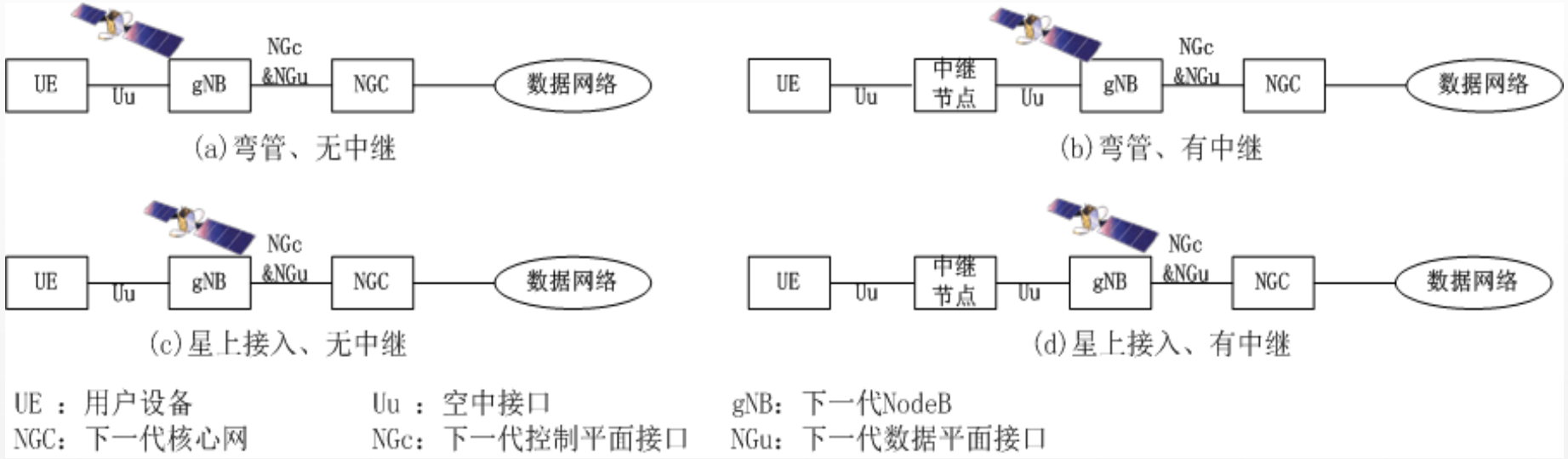
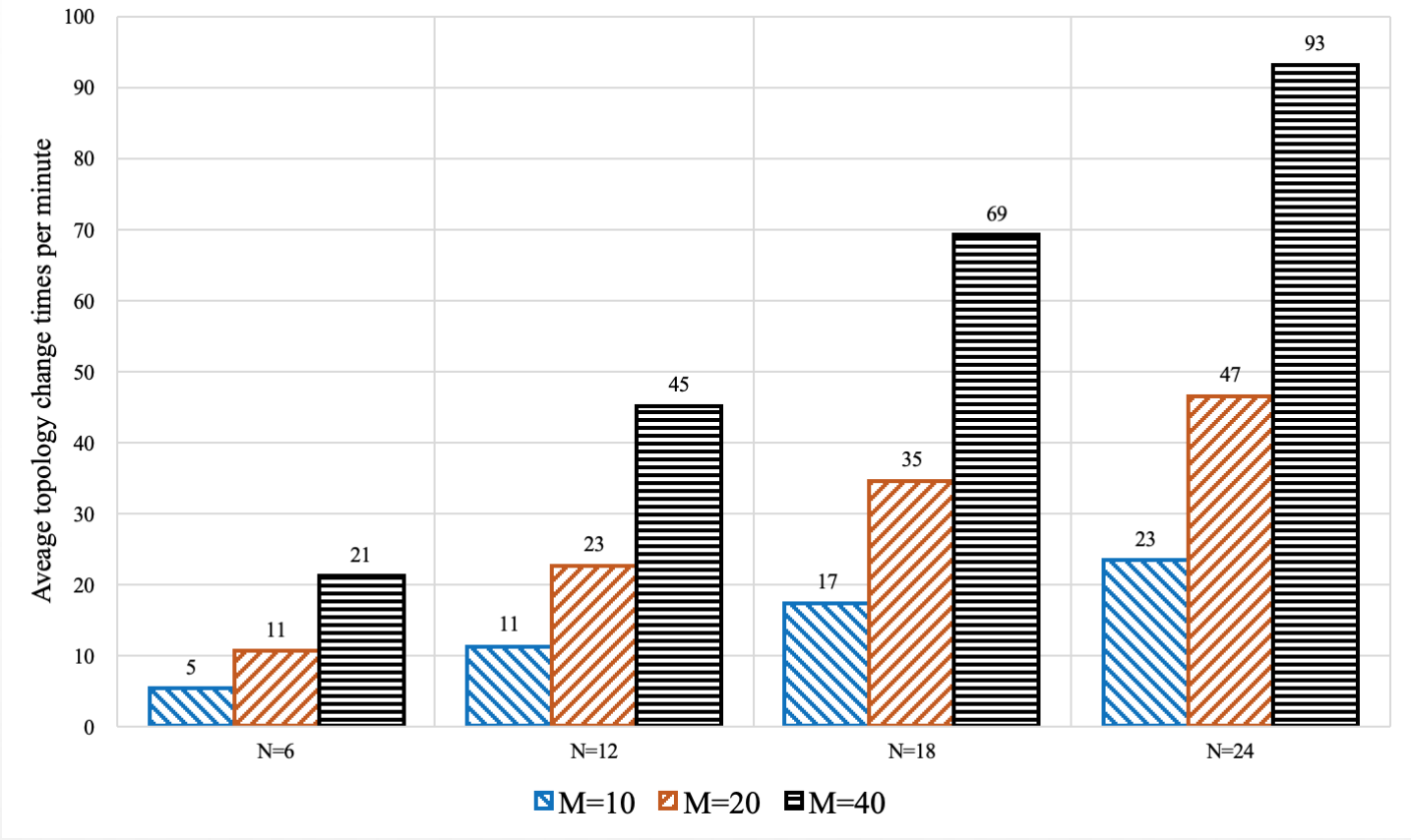
# Satellite Using Scenarios in 5G

- 5G+Satellite <> 5G+Satellite Network
- With the wide-area coverage capability of satellites, operators can provide 5G commercial services in underdeveloped place and realize 5G services continuity, especially in emergency communication, maritime communication, aviation communication, railway communication and other scenarios.



# Result: Topology stability

| Factors | Meaning |
|---|---|
| $N$ | the number of orbits |
| $M$ | the number of satellites per orbit |
| $G$ | the number of ground stations |
| $p$ | the process time in each satellite node(described in III-C) |



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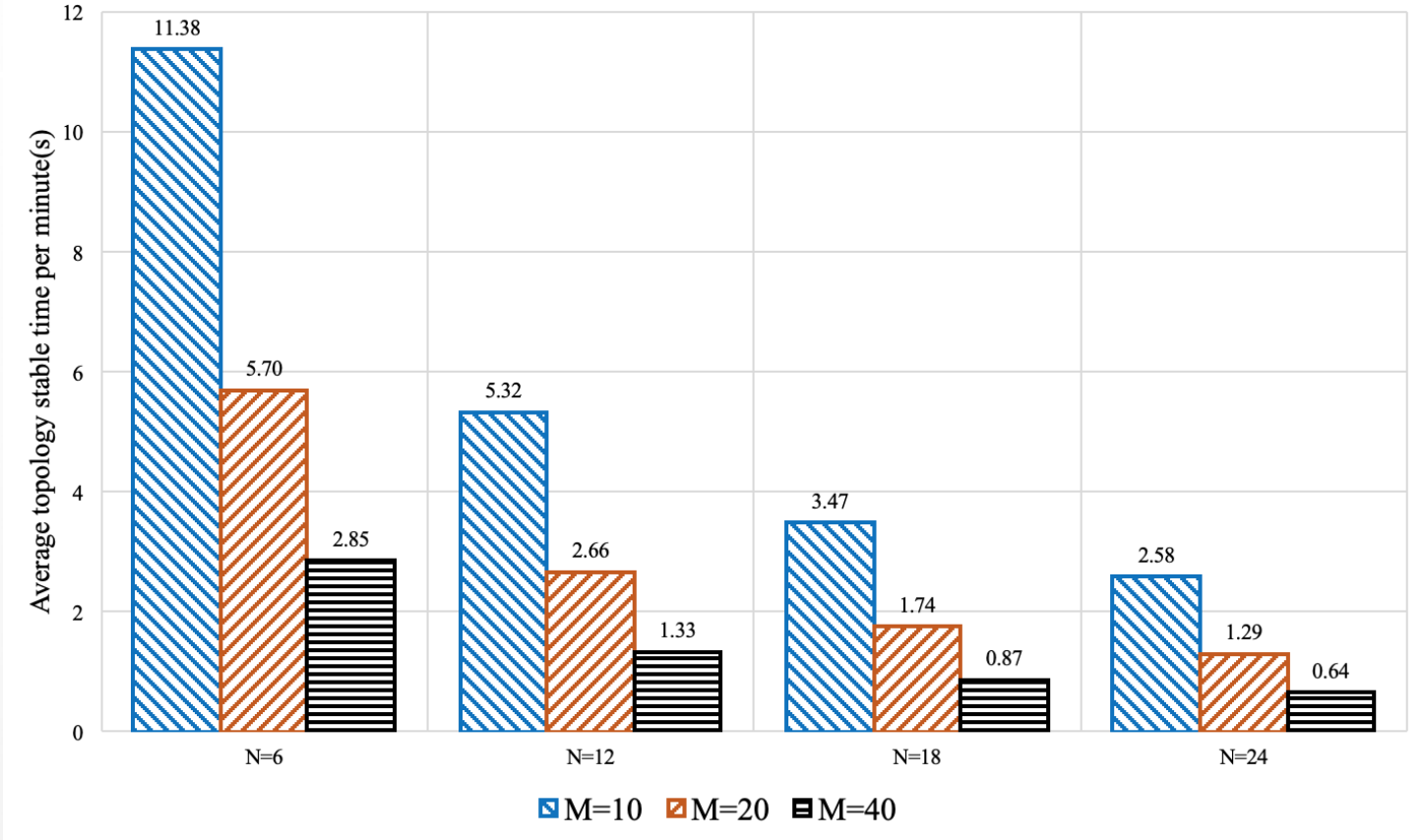
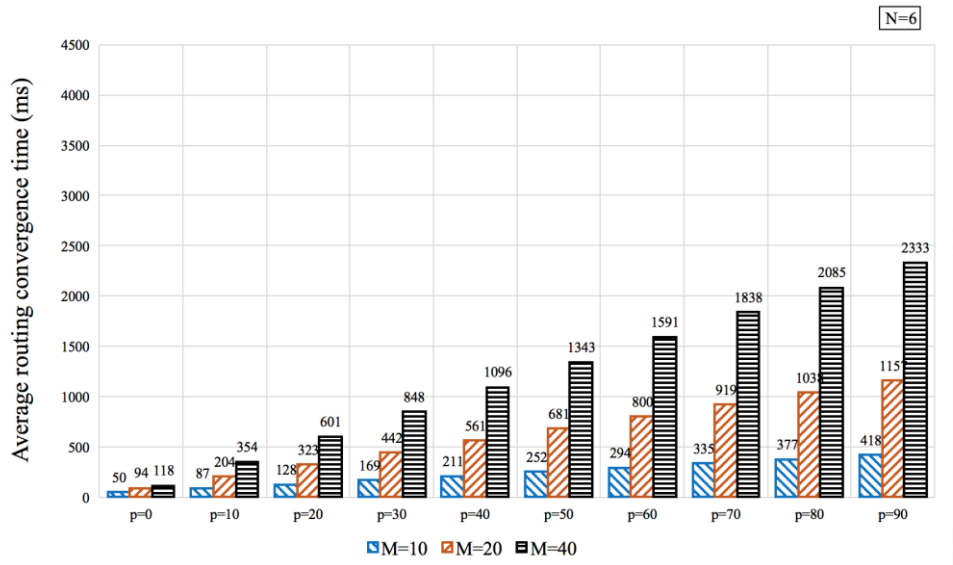
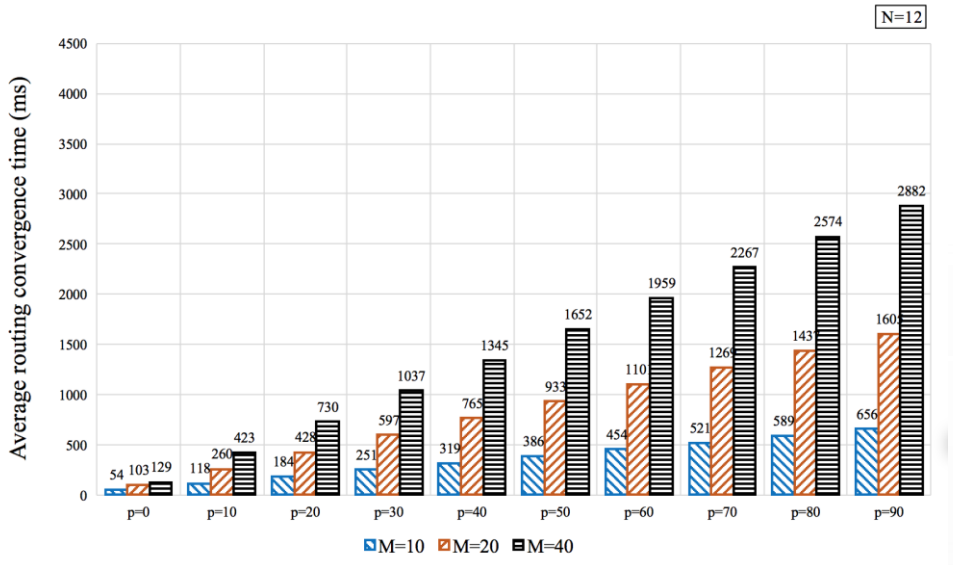
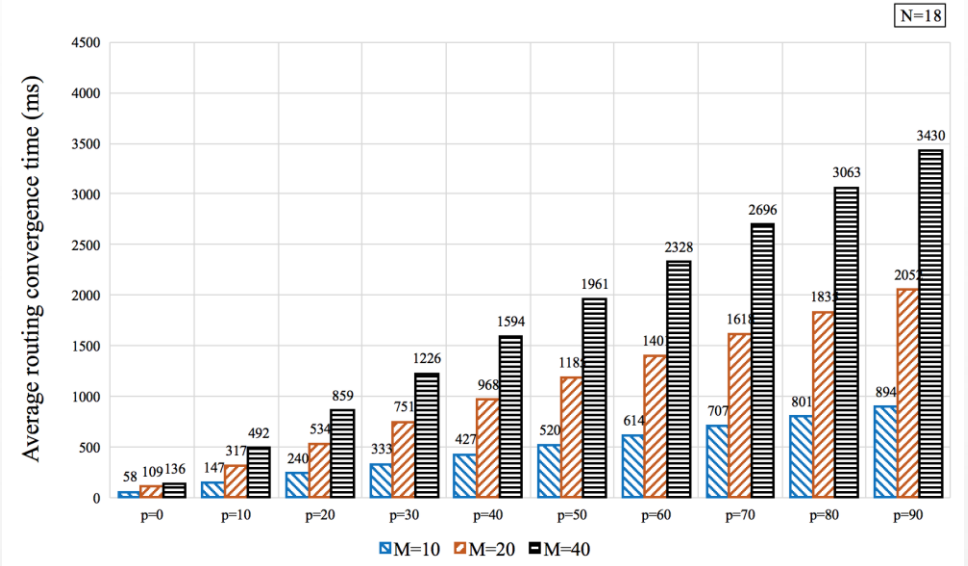
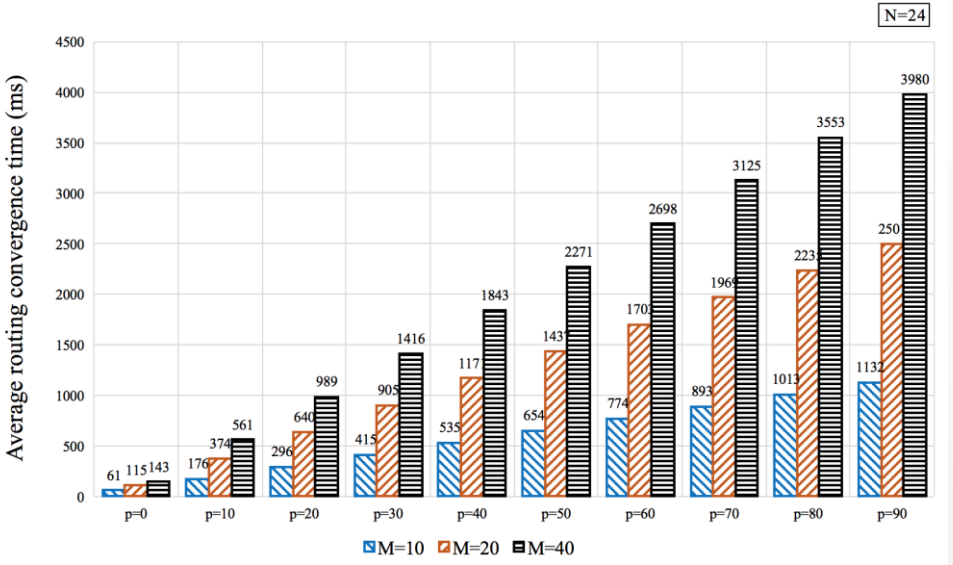


# Result: Routing Coverage



# Result: Routing Usability

TABLE III
ROUTING USABLE TIME AND ROUTING USABLE PERCENTAGE IN ONE DAY PERIOD IN SATELLITE NETWORK

| Satellite Network | | p=0ms | | p=10ms | | p=20ms | | p=30ms | | p=60ms | | p=90ms | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M = 10 | N = 6 | 23.75$h$ | 98.97% | 23.56$h$ | 98.19% | 23.36$h$ | 97.35% | 23.16$h$ | 96.48% | 22.53$h$ | 93.88% | 21.91$h$ | 91.28% |
| | N = 12 | 23.43$h$ | 97.61% | 22.76$h$ | 94.82% | 22.06$h$ | 91.92% | 21.35$h$ | 88.94% | 19.20$h$ | 80.01% | 17.45$h$ | 72.72% |
| | N = 18 | 23.07$h$ | 96.14% | 21.63$h$ | 90.14% | 20.14$h$ | 83.91% | 18.63$h$ | 77.62% | 16.38$h$ | 68.25% | 15.64$h$ | 65.17% |
| | N = 24 | 22.68$h$ | 94.52% | 20.18$h$ | 84.08% | 17.76$h$ | 74.01% | 16.48$h$ | 68.68% | 15.18$h$ | 63.24% | 13.87$h$ | 57.79% |
| M = 20 | N = 6 | 23.50$h$ | 97.92% | 22.93$h$ | 95.53% | 22.30$h$ | 92.92% | 21.67$h$ | 90.31% | 19.79$h$ | 82.47% | 17.91$h$ | 74.63% |
| | N = 12 | 22.84$h$ | 95.18% | 21.09$h$ | 87.88% | 19.21$h$ | 80.04% | 17.33$h$ | 72.21% | 12.02$h$ | 50.10% | 9.59$h$ | 39.96% |
| | N = 18 | 22.14$h$ | 92.23% | 18.59$h$ | 77.46% | 14.88$h$ | 62.01% | 11.63$h$ | 48.47% | 8.61$h$ | 35.88% | 7.04$h$ | 29.33% |
| | N = 24 | 21.36$h$ | 88.99% | 15.42$h$ | 64.23% | 10.43$h$ | 43.46% | 8.98$h$ | 37.40% | 6.32$h$ | 26.31% | 4.44$h$ | 18.49% |
| M = 40 | N = 6 | 22.99$h$ | 95.79% | 21.00$h$ | 87.50% | 18.90$h$ | 78.75% | 16.80$h$ | 70.01% | 10.73$h$ | 44.71% | 7.16$h$ | 29.85% |
| | N = 12 | 21.66$h$ | 90.27% | 16.35$h$ | 68.14% | 10.80$h$ | 44.99% | 7.20$h$ | 29.99% | 3.35$h$ | 13.95% | 1.93$h$ | 8.03% |
| | N = 18 | 20.23$h$ | 84.29% | 10.44$h$ | 43.50% | 5.14$h$ | 21.42% | 3.33$h$ | 13.87% | 1.28$h$ | 5.32% | 0.34$h$ | 1.40% |
| | N = 24 | 18.66$h$ | 77.76% | 6.19$h$ | 25.81% | 2.99$h$ | 12.46% | 1.60$h$ | 6.66% | 0.09$h$ | 0.37% | 0.00$h$ | 0.00% |

nearly no usable time

TABLE IV
ROUTING USABLE TIME AND ROUTING USABLE PERCENTAGE IN ONE DAY PERIOD IN SATELLITE NETWORK IN ISTN

| ISTN | | p=0ms | | p=10ms | | p=20ms | | p=30ms | | p=60ms | | p=90ms | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M = 10 | N = 6 G = 3 | 23.70$h$ | 98.74% | 23.45$h$ | 97.73% | 23.21$h$ | 96.71% | 22.97$h$ | 95.69% | 22.23$h$ | 92.62% | 21.49$h$ | 89.55% |
| | N = 12 G = 5 | 23.21$h$ | 96.72% | 22.36$h$ | 93.19% | 21.48$h$ | 89.52% | 20.59$h$ | 85.79% | 17.90$h$ | 74.59% | 15.63$h$ | 65.14% |
| | N = 18 G = 7 | 22.57$h$ | 94.03% | 20.60$h$ | 85.85% | 18.53$h$ | 77.22% | 16.48$h$ | 68.67% | 12.74$h$ | 53.08% | 10.36$h$ | 43.18% |
| | N = 24 G = 9 | 21.67$h$ | 90.29% | 17.85$h$ | 74.35% | 14.19$h$ | 59.12% | 12.04$h$ | 50.17% | 7.48$h$ | 31.15% | 4.46$h$ | 18.60% |
| M = 20 | N = 6 G = 3 | 23.30$h$ | 97.10% | 22.40$h$ | 93.33% | 21.49$h$ | 89.54% | 20.58$h$ | 85.74% | 17.85$h$ | 74.36% | 15.11$h$ | 62.97% |
| | N = 12 G = 5 | 22.21$h$ | 92.52% | 19.55$h$ | 81.45% | 16.86$h$ | 70.26% | 14.16$h$ | 59.02% | 7.94$h$ | 33.07% | 5.60$h$ | 23.32% |
| | N = 18 G = 7 | 20.74$h$ | 86.43% | 15.29$h$ | 63.69% | 9.91$h$ | 41.27% | 6.65$h$ | 27.72% | 2.41$h$ | 10.05% | 0.96$h$ | 4.01% |
| | N = 24 G = 9 | 18.77$h$ | 78.20% | 9.20$h$ | 38.31% | 4.40$h$ | 18.35% | 1.91$h$ | 7.96% | 0.04$h$ | 0.16% | 0.00$h$ | 0.00% |
| M = 40 | N = 6 G = 3 | 22.50$h$ | 93.74% | 18.91$h$ | 78.78% | 15.31$h$ | 63.81% | 11.73$h$ | 48.89% | 5.10$h$ | 21.25% | 2.63$h$ | 10.95% |
| | N = 12 G = 5 | 20.18$h$ | 84.08% | 10.62$h$ | 44.26% | 4.27$h$ | 17.79% | 1.87$h$ | 7.79% | 0.10$h$ | 0.42% | 0.00$h$ | 0.00% |