# 6CNIS: An Efficient IPv6 Cellular Network Identification System

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***Abstract*—With the rapid development of 5G technology and the Internet of Things, the high-speed, low-latency, and massive connectivity capabilities have made cellular networks a critical infrastructure. However, IPv6 cellular address identification, crucial in cellular network measurement, remains a significant gap. On the one hand, the combination of IPv6 with 5G renders existing methods ineffective; on the other hand, the vast address space of IPv6 makes large-scale network scanning infeasible. To address this gap, we propose a novel IPv6 cellular network identification system, leveraging round-trip time and IPv6 interface identifiers to classify network connection types for /48 prefixes accurately. Our method achieves an accuracy of over 99% on publicly available global datasets. Furthermore, by incorporating target generation scans, we have first achieved large-scale probing worldwide.**

## I. Introduction

With the depletion of traditional IPv4 addresses, IPv6 has evolved as a critical technology in network communication [1]. Nowadays, IPv6 is rapidly expanding worldwide, with an overall deployment rate of 36.5%. Parallelly, cellular networks have also seen significant growth, with the deployment rate of IPv6 in cellular networks among ISPs surpassing 80%, significantly higher than that of fixed-line networks. Concomitantly, there is an increasing need to map the state of cellular networks and services quickly, especially IPv6 cellular address identification and large-scale probing.

This paper proposes an efficient IPv6 cellular Network identification system (6CNIS)[1]. Specifically, we utilize round-trip time (RTT) and interface identifiers (IIDs) to precisely **identify IPv6 cellular networks with a /48 prefix** instead of traditional methods that focus on discovering individual active IPv6 cellular addresses. Additionally, we combine a target address generation algorithm to **achieve Internet measurement**.

Identifying network connection types at the /48 prefix level proves both meaningful and feasible. The significance stems from two key factors: (1) *Individual IPv6 addresses exhibit high volatility*, with 19% active for less than one hour and 39.4% for no more than eight hours, making prefix-level analysis more stable than individual address tracking; (2) *Addresses within the same /48 prefix typically share identical network connectivity characteristics*, as ISPs predominantly allocate /48 or longer prefixes for cellular infrastructures. Cellular networks' distinct characteristics support the feasibility: 1) The radio resource control (RRC) mechanism introduces *measurable RTT variations* during state transitions, enabling differentiation from fixed-line networks. 2) Network types exhibit *distinct IPv6 address allocation patterns*.

Specifically, we **extract statistical features from RTT and IID distributions** based on the RTR-NetTest dataset collected from September 2023 to August 2024. We then **train a classifier** utilizing these characteristics to predict the type of network connection. Furthermore, we scan IPv6 within several ISPs and confirm the network connections of these prefixes by WHOIS and IP-API to **construct a validation dataset**, where 6CNIS achieves an accuracy rate of 99.63%, improving 6.76% over previous approaches [2]. Subsequently, by incorporating the target address generation method, we enable **large-scale scanning of IPv6 cellular networks globally**.

## II. IPv6 Cellular Network Identification

6CNIS identifies the network connection types of /48 prefixes, improving identification accuracy and adapting to large-scale IPv6 network measurements.

As shown in Fig. 1, 6CNIS training can be divided into four stages: dataset construction, feature extraction, model training, and address identification. 1) **Dataset construction** collects /48 prefixes with labels from public datasets, and the accuracy of these prefixes is confirmed by eliminating aliases and verifying the information using IP-API. Then, a single probe is used to detect active IP addresses to create the training dataset. 2) **Feature extraction** involves identifying features related to round-trip time (RTT) and interface identifiers (IID) from the training dataset, followed by filtering features based on their importance. 3) **Model training** realizes six commonly used machine learning models and selects the best-performing one as the final. 4) **Address identification** utilizes 6CNIS to classify detected IP addresses and identify cellular addresses.

Fig 2 shows the performances of 6CNIS and the state-of-the-art [2], which solely relies on the RTT characteristics to identify cellular /48 prefixes. While both methods perform highly accurately on fixed-line network identification, 6CNIS demonstrates a clear advantage in predicting cellular prefixes, maintaining an accuracy of 99.63%, which is 6.76% higher.

## III. Global Cellular Network Measurement

6CNIS conducts large-scale network scanning using HMap6 [3], identifying cellular prefixes distributed across approximately a hundred countries and hundreds of ASes. As shown

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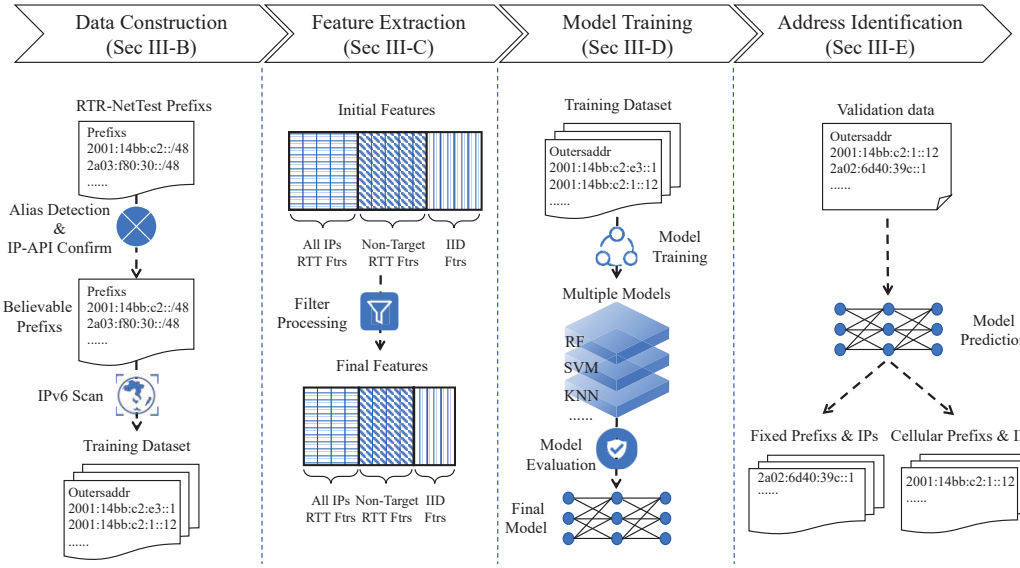


Fig. 1: The overview of 6CNIS.

TABLE I: The distribution of IPv6 addresses among countries.

(a) The top 10 countries by alive IPv6 addresses.

| Country | # of prefixes | # of addresses | Addresses proportion |
|---|---|---|---|
| China | 50,289 | 112.56M | 46.05% |
| India | 9,668 | 49.70M | 20.33% |
| United States | 27,038 | 20.58M | 8.42% |
| France | 6,172 | 8.1M | 3.31% |
| Brazil | 15,580 | 7.51M | 3.07% |
| United K | 52,406 | 6.18M | 2.53% |
| Malaysia | 769 | 4.64M | 1.90% |
| Thailand | 439 | 3.72M | 1.52% |
| Mexico | 1,599 | 3.43M | 1.40% |
| Ukraine | 476 | 3.26M | 1.33% |

(b) The top 10 countries by alive IPv6 cellular addresses.

| Country | # of cellular prefixes | # of cellular addresses | Cellular addresses proportion |
|---|---|---|---|
| China | 23,565 | 66.17M | 48.66% |
| India | 7,400 | 47.62M | 35.02% |
| Malaysia | 656 | 4.61M | 3.39% |
| Thailand | 377 | 3.48M | 2.56% |
| Ukraine | 413 | 3.20M | 2.35% |
| Brazil | 400 | 2.04M | 1.50% |
| Russia | 228 | 1.09M | 0.80% |
| Finland | 108 | 0.98M | 0.72% |
| Guatemala | 40 | 0.67M | 0.50% |
| Peru | 28 | 0.60M | 0.44% |

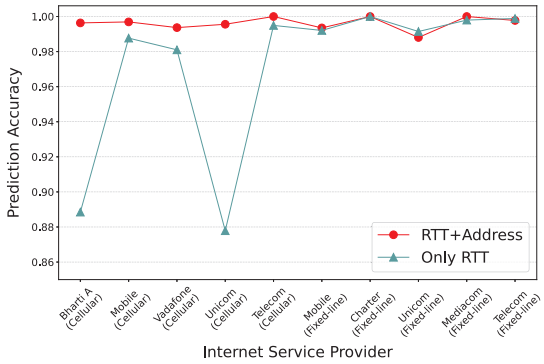


Fig. 2: Model comparison on validation datasets.

in Tab. I, cellular IPv6 addresses are highly concentrated in China (66.17M, 48.66%) and India (47.62M, 35.02%). This is due to two factors: 1) China and India are key players in the global 5G market, driving cellular network development. 2) ISPs allocate network prefixes of varying lengths. China's 64-bit prefixes allow for many /48 prefixes to be retained during high-value selection.

## IV. Conclusion

In this paper, we propose 6CNIS, an accurate and efficient method to identify IPv6 cellular networks. By analyzing the RTT and IID characteristics of active addresses within /48 prefixes, 6CNIS successfully identifies cellular networks with an accuracy of 99.63%, surpassing the state-of-the-art by 6.76%. Additionally, 6CNIS performs a comprehensive identification for cellular addresses, recognizing cellular prefixes from the large-scale worldwide Internet.

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