NDN-Based ICN Architecture Design to Improve Data Communication QoS in Kertajati Aerocity

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***Abstract*—The development plan for Kertajati Aerocity requires adequate support from the data communication infrastructure. The primary challenge lies in the dense data flows, which involve very large volumes and diverse data types. The commonly used host-centric architecture suffers from latency, bandwidth utilization, and scalability issues, making it unsuitable for the dynamic Aerocity scenario. To address these limitations, this study proposes an Information-Centric Networking (ICN) architecture based on Named Data Networking (NDN), where communication relies on content names rather than IP addresses. The ndnSIM simulator was employed in the experimental evaluation of this architectural model, using operational data requirements derived from the Taoyuan Aerotropolis case. Performance was assessed through Quality of Service (QoS) metrics, including throughput, latency, and cache hit ratio. The simulation results indicate that throughput stabilized at ~10.1 Mbps (from 7.2 Mbps initially) with balanced node distribution, while latency averaged ~3 ms, with p95 < 10 ms and over 95% of requests completed within low-delay bounds despite initial spikes. Cache statistics were unavailable (CacheHits/Misses = 0) due to tracer settings and traffic patterns, so cache analysis is left for future work. These findings highlight the novelty of integrating NDN-based ICN with Aerocity-specific traffic requirements. The proposed model is presented as a scalable solution for the evolving data communication infrastructure of Kertajati Aerocity in the future, emphasizing designing an NDN-based architecture specifically designed for the multi-zone Aerocity ecosystem, including hierarchical and cross-zone naming schemes that model the operational flow of Aerocity.**

***Keywords*—Aerocity; Information-Centric Networking (ICN); Named Data Networking (NDN); Quality of Service (QoS); ndnSIM**

I. INTRODUCTION

The development plan for Kertajati Aerocity positions itself as a model city that integrates the airport with surrounding economic and logistics activities, making it a multimodal hub [1]–[5]. This creates the need for data communication technologies capable of handling dense connections, diverse traffic flows, and dynamic service demands [6], [7]. Such conditions require a communication network infrastructure that supports low latency, efficient bandwidth usage, and scalable network operations.

Meanwhile, the current Internet architecture is fundamentally host-centric, designed for communication between hosts identified by IP addresses [8], [9]. This model presents limitations when applied to today's conditions, particularly issues such as data retrieval latency, inefficient handover management, and bandwidth bottlenecks, which emerge as critical problems [10], [11]. These challenges necessitate a transition towards a more data-centric architecture that is scalable and adaptable to environments such as Aerocity [10]–[13].

At present, Information-Centric Networking (ICN) has emerged as a promising paradigm for the future Internet. By focusing on the requested content rather than the host's location, ICN offers advantages in caching, name-based routing, and data-centric forwarding [14], [15]. Within this paradigm, Named Data Networking (NDN) stands out as a well-developed and mature approach. NDN simplifies data retrieval, enhances resilience through caching, and enables efficient multicast distribution [16]–[18].

Despite these strengths, most research on NDN has focused on domains such as vehicular networks, content delivery, and IoT systems [19], [20]. Very little attention has been paid to Aerocity environments, which combine the high data density of urban centers with domain-specific requirements for logistics, utilities, and business ecosystems. The complexity of traffic patterns and service heterogeneity in the Aerocity scenario presents unique challenges that have not been fully addressed in previous ICN/NDN studies.

Therefore, there is a research gap where, although NDN provides a fundamental mechanism for data-centric communication, there is no specific architectural design designed to meet the operational requirements in the Aerocity environment. In response to this gap, this study proposes an NDN-based ICN architecture specifically designed for the needs of Aerocity. This architecture emphasizes an NDN design specifically for the multi-zone Aerocity ecosystem, which, to our knowledge, has not been addressed in previous NDN or ICN studies, including hierarchical and cross-zone naming schemes that model the operational flow of Aerocity.

The remainder of this study is organized as follows: Section II reviews related work on NDN and its applications. Section III presents the proposed architecture. Section IV describes the methodology. Section V provides the results and discussion. Finally, Section VI concludes the study.

II. RELATED WORK

The paradigm shift from host-centric, IP-based networking to content-oriented communication has driven ongoing

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research into architectures that leverage the advantages of this new model. Unlike IP networks that rely on host addresses, Named Data Networking (NDN) enables data retrieval based on content names, making it better suited to modern, dynamic, distributed, and data-intensive networking environments.

Research on NDN remains active across multiple domains, including forwarding, routing, caching, security, and mobility support. These areas continue to be studied because many challenges in modern networks, such as high latency, data availability in mobile environments, efficient caching, and reliable communication in heterogeneous topologies, are not fully addressed by existing approaches. Therefore, investigations that strengthen existing findings, expand application scenarios, and evaluate NDN architectures in new environments such as Aerocity areas remain highly relevant and necessary [21], [22].

Aerocity environments, characterized by high mobility, heterogeneous nodes (RSUs, vehicles, drones, and ground infrastructure), and intensive cross-zone communication, introduce unique challenges that are not adequately addressed in previous NDN research. This highlights the importance of the architectural design study conducted by the authors, as Aerocity environments combine real-time communication needs, inter-zone mobility, and content-centric information exchange that are uncommon in traditional network models.

The use of ndnSIM is particularly appropriate because the simulator implements the core NDN components, including PIT, FIB, CS, and Interest/Data exchange semantics, allowing comprehensive QoS evaluation without the need for complex or costly physical infrastructure. Simulation also provides flexibility to explore various topology configurations, adaptive routing strategies, caching mechanisms, and mobility scenarios in a controlled and reproducible manner [21], [23].

Previous studies have examined the implementation of NDN across several network models, such as VANETs, IoT systems, smart cities, UAV networks, and edge fog environments, using different optimization strategies for NDN components. However, there is still limited research that specifically evaluates NDN in Aerocity contexts, which feature multi-zone structures, interactions across multiple modes of transportation, and complex mobility dynamics. Accordingly, this study contributes to broadening the scope of NDN research and provides empirical evidence of NDN's potential in future networking environments characterized by high mobility.

NDN architecture transforms the approach to data retrieval from a host-centric to a content-name-based model. Numerous studies on NDN have been conducted, and this section reviews research on data-centric communication, routing, forwarding, caching, and security in NDN.

Data retrieval in NDN begins when a consumer sends an Interest into the network and receives the corresponding Data packet from the producer, following the reverse path of the Interest. NDN employs three key data structures: the Pending Interest Table (PIT), the Forwarding Information Base (FIB), and the Content Store (CS) [24]–[26]. The PIT records all Interests forwarded by a router that have not yet been satisfied. When an Interest packet arrives, the router first checks the Content Store to find matching data. If no matching data is found, the router examines the PIT and forwards the Interest to the producer based on the FIB. However, if the Content Store contains the requested data, the Data is returned directly through the interface.

Regarding content naming from a source, whether through a flat or hierarchical approach, the Attribute-Based Encryption (ABE) method is employed. This approach involves three roles in content generation: the content owner, the content user, and the content to be encrypted. To obtain content, users use a name search service via a routing process known as name-based routing. Two types of attributes are used in this approach to generate content names: subject attributes and object attributes, both of which contribute to forming attribute control and attribute descriptions. For security purposes, encryption and decryption algorithms are applied during the construction of the content naming scheme.

Routing and forwarding in Named Data Networking (NDN) adopt a fundamentally different approach from traditional IP-based networks, operating on content names rather than host addresses. In the routing plane, NDN utilizes name-based routing protocols to disseminate content prefixes and construct the Forwarding Information Base (FIB), allowing routers to determine the most suitable paths to data producers or in-network caches. This design supports dynamic topology changes and ensures resilience in mobility scenarios, particularly through adaptive strategies that prioritize latency reduction and traffic load distribution [23], [24], [27].

In the forwarding plane, decisions are made locally at each router based on three main data structures: the Content Store (CS), the Pending Interest Table (PIT), and the FIB. When an Interest packet is received, the router first checks the CS to satisfy the request from cached Data, thereby reducing retrieval delays. If no match is found, the router examines the PIT to aggregate identical Interests and enable efficient multicast delivery of returning Data. If the Interest is new, the router refers to the FIB to forward the request to the appropriate interface. Once a Data packet arrives, it is distributed to all consumers listed in the PIT and stored in the CS for future access. Caching strategies in the context of Named Data Networking (NDN) refer to the methods for determining when, where, and what content is stored in network node caches. The objective is to reduce latency by serving data directly from the nearest cache, save bandwidth by avoiding redundant traffic, and enhance reliability by ensuring data availability even when the producer is offline [28]–[31].

Security in Named Data Networking (NDN) is data-centric, shifting the trust model from communication channels to the content itself. Data is secured using digital signatures and encryption, ensuring authenticity and integrity. Unlike IP-based architectures that primarily secure point-to-point connections, NDN ensures that every Data packet is cryptographically signed by its producer, enabling source authentication and integrity verification regardless of the retrieval path [32], [33].

Overall, the NDN security framework provides intrinsic content protection, offers resilience against communication channel attacks, and supports reliable communication in dynamic environments such as smart cities and Aerocity networks.

III. Proposed Architecture

The objective of proposing this architecture is to design a model that addresses the challenges of dense connectivity, diverse traffic flows, and the multiple interacting domains within the Aerocity environment. The proposed architecture adopts the Information-Centric Networking (ICN) paradigm based on Named Data Networking (NDN) with a topology-driven approach. The design connects consumer nodes distributed across various Aerocity zones directly to an interconnected NDN router network. Routers are positioned according to the physical map and functional structure of

Data Requirements and Example Data Prefixeswere obtained through a synthesis of multiple sources, including government planning documents on the Taoyuan Aerotropolis, open datasets on transportation, logistics, and utilities, and academic literature on smart city infrastructure and information-centric networking. Rather than relying on a single source, this study identified consistent traffic patterns from various references and translated them into the Named Data Networking (NDN) framework. Each functional zone (Logistics, Transport, Industrial, Commercial–Residential, and Utilities/Smart Infrastructure) was mapped in terms of consumers, producers, data prefixes, and traffic characteristics, including proceedings that map key factors in Aerotropolis development and information requirements for decision-making [34]. On this basis, the data patterns in the logistics, transportation, industrial, commercial–residential, and utilities zones are translated into producer–consumer mappings within the NDN approach Architecture Description.

B. Architecture Description

The architecture topology consists of several NDN routers placed in each zone. Consumer nodes within a given zone send Interests to the local router, which then searches the FIB, PIT, and Content Store. If the data is unavailable, the Interest is forwarded to neighboring routers or to the data center according to the Aerocity interconnection map. The router in the logistics zone is closely linked to the cargo data distribution center. The router in the transportation zone connects to roadside units (RSUs) and the airport information system. The router in the industrial zone links factory sensors to the

Aerocity, ensuring that the architecture reflects real-world conditions. The goal is to guarantee flexibility, routing efficiency, and alignment with the specific data requirements of each zone.

Each zone (Logistics, Transport, Industrial, Commercial–Residential, Utilities) contains two NDN routers (serving as inter-zone gateways), several consumers (represented by small green nodes), and one producer (represented by a purple node). The zone routers are connected to the NDN mesh routers (three routers forming a triangle), following the same mapping as the scenario.

A. Data Requirements

The data requirements presented in analytics system. The commercial and residential router connects to multimedia services and customer applications. Thus, the communication flow is not constrained by a layered hierarchy but is instead determined by inter-zone relationships and the actual infrastructure, as shown in Aerocity area network architecture design based on NDN (Physical Layout + Interest/Data Overlay).

C. Workflow or Communication Flow

The communication process begins when a consumer in a given zone sends an Interest packet to the local router. The router checks the Content Store; if a cache hit occurs, the Data is immediately returned. If a cache miss occurs, the Interest is forwarded to an inter-zone router or directly to the producer, depending on the FIB. The producer (e.g., a logistics data center or an airport information system) sends the Data, which is then returned along the same path. Along this path, the Data may be cached at intermediate routers to ensure that the selected forwarding path operates under optimal traffic conditions, thereby maintaining network efficiency even in high-mobility scenarios. These routers are interconnected to form a mesh topology consistent with the physical design of Aerocity, enabling multiple routing paths between consumers and producers. This structure ensures the evaluation of both cache hit and cache miss scenarios. These routers are interconnected to form a mesh topology that is consistent with the physical design of Aerocity, enabling multiple routing paths between consumers and producers. This structure ensures the evaluation of both cache hit and cache miss scenarios.

TABLE I. Data Requirements and Example Data Prefixes

Zone	Consumers	Producers	Example Data / Prefix	Traffic Characteristics
Logistics	Warehouses, distribution centers, cargo operators	Cargo management systems, logistics tracking databases	/logistics/cargo/ /logistics/tracking/	Periodic (1–2s), high volume
Transport	Vehicles, traffic management applications	Airport information systems, traffic management servers	/transport/traffic/ /transport/flights/	Bursty (peak hours), real-time
Industrial	Factories, IIoT machines, production operators	Industrial analytics platforms	/industrial/iiot/	Medium-periodic, critical data
Commercial–Residential	Retail apps, households, multimedia service users	e-commerce servers, customer service platforms	/commerce/media/ /residential/services/	Zipf-like popularity, heavy content
Utilities / Smart Infrastructure	IoT sensors (energy, water, CCTV), public safety units	Energy/water utility servers, municipal security centers	/utilities/energy/ /utilities/water/	Low-volume periodic, persistent

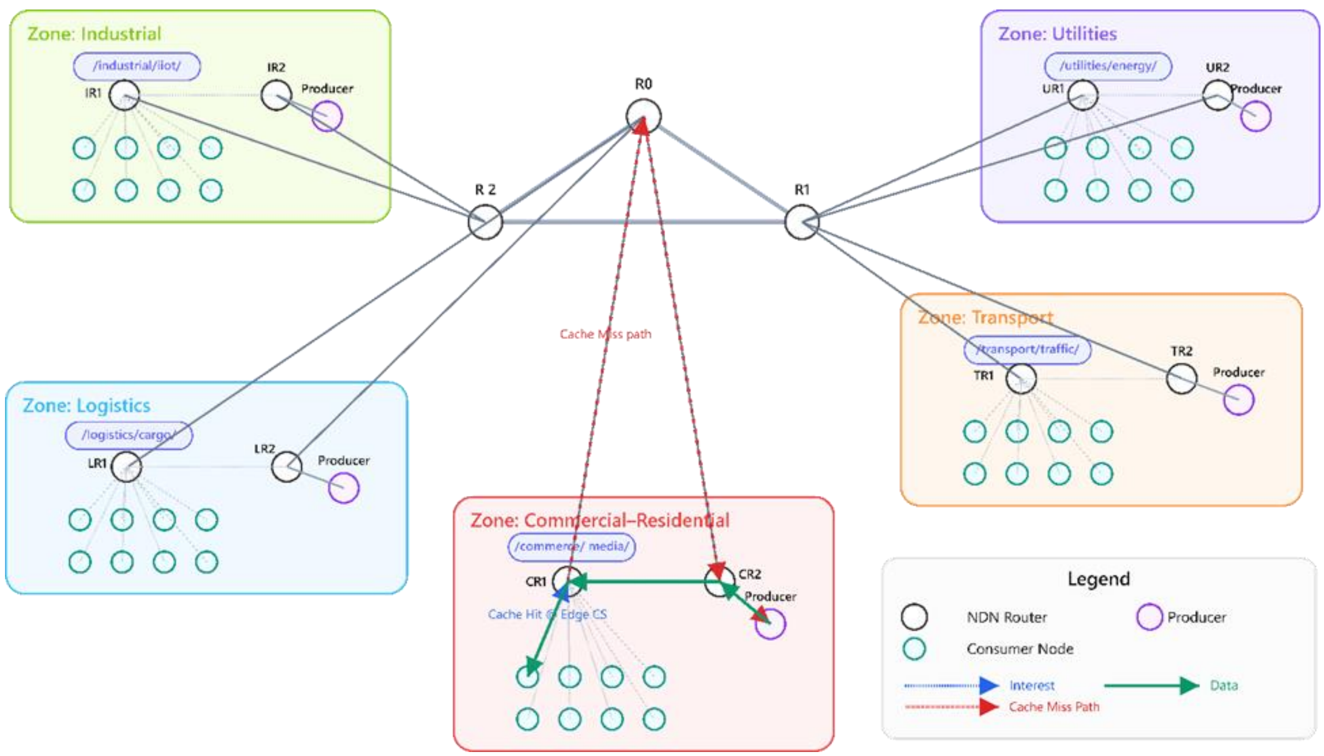

Fig. 1. Aerocity area network architecture design based on NDN (Physical Layout + Interest/Data Overlay).

D. *Traffic Model*

Traffic flows are generated to emulate realistic Aerotropolis operations. Logistics Zone, periodic Interests for cargo status updates at intervals of 1 to 2 seconds. Transport Zone, Interests for real-time traffic information and flight schedules, modeled as burst traffic during peak hours. Industrial Zone, Interests for IIoT telemetry control messages with medium periodicity. Commercial and Residential Zone, Interests for video streaming and web services with a Zipf content popularity distribution. Utilities Zone: sensor-based Interests for energy and water data, modeled as low-volume periodic flows.

IV. METHODOLOGY

A. *Simulation Environment*

This study employs ndnSIM as the standard simulator for Named Data Networking (NDN) research [35], [36], as it fully supports the core NDN components while providing flexibility for scenario development and topology modifications tailored to Aerocity requirements, and was executed on Ubuntu 22.04 LTS. The simulation configuration activates the main components of the NDN forwarding plane, namely the Content Store (CS), Pending Interest Table (PIT), and Forwarding Information Base (FIB). Additionally, python scripts are utilized to analyze the simulation results. The simulation was run for 60 seconds using the BestRoute forwarding strategy, with tracers sampled every second. A Content Store of 10,000 entries (LRU policy) and producer payloads of 1024 bytes were configured, and results were exported in CSV format for throughput, cache performance, and delay analysis.

B. *Network Topology*

The experimental topology reflects the Kertajati Aerocity model, consisting of several functional zones, including Logistics, Transport, Industrial, Commercial–Residential, and Utilities, as shown in ndnSIM Visualizer displaying the simulation topology and node-level state information during runtime. The visualization of the simulation process is generated using ndnSIM. Each zone is equipped with Consumer nodes, which generate Interest packets for data such as logistics tracking, traffic information, industrial control messages, multimedia content, and IoT sensor data. NDN routers, strategically placed to represent inter-zone gateways, are responsible for forwarding Interest–Data flows. Producer nodes, which provide authoritative data repositories, such as cargo databases, traffic management systems, and utility monitoring centers. The experimental topology models a multi-zone Aerocity network with five functional zones: Logistics (8 nodes), Transport (8), Industrial (6), Commercial–Residential (10), and Utilities (10), and Utilities (10). Each zone is connected to a single aggregation node (five total), while a three-node core backbone (R0, R1, R2) provides inter-zone connectivity.

C. *Performance Metric*

To evaluate the efficiency of the proposed NDN-based architecture, experiments were conducted using several Quality-of-Service metrics. These metrics serve as the primary indicators for measuring network performance, focusing on how the architecture handles data delivery, latency, cache utilization, and overall reliability in an Aerocity environment. The calculation of Quality-of-Service metrics from simulation output data was performed using a Python-based program that facilitates the computation and ensures higher accuracy.

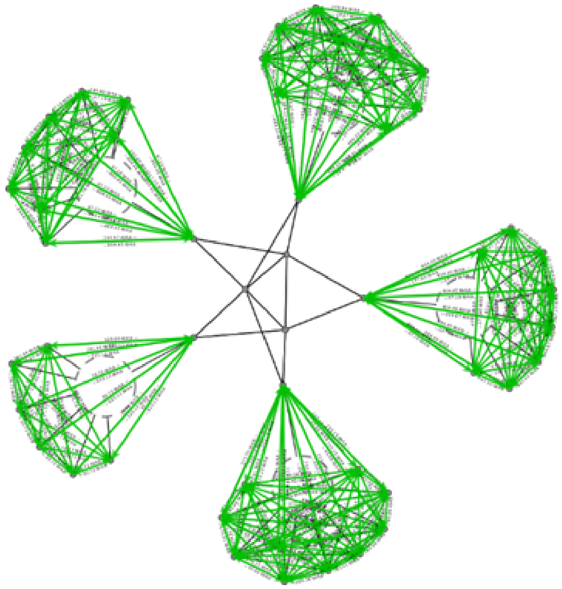

Fig. 2. ndnSIM Visualizer displaying the simulation topology and node-level state information during runtime.

Three output files that are used for analyzing the performance metrics of the NDN network, namely rate-trace.csv, app-delay-trace.csv, and cs-trace.csv.

The rate-trace.csv file stores Interest, Data, and byte statistics for each node, which can be used to calculate throughput (bits/s), packet delivery rate, and node-by-node traffic.

First 10 Entries from the File Rate-Trace.presents the first ten entries from the rate-trace.csv file.

Throughput is defined as the volume of data successfully delivered to the consumer per unit time, Δt. The formula is expressed as:

$$T = \frac{S}{\Delta t} \text{(bit/s)} \tag{1}$$

where, S is the total number of Data bits successfully received during the interval Δt.

To calculate and generate the throughput-related graph for this experiment, a python-based application was used. Furthermore, the app-delay-trace.csv file is used to log the application-level delay (Interest → Data) for each packet, which is then used to compute application-level latency. First 10 Entries from the File App-Delay-Trace.presents the first 10 entries from the app-delay-trace.csv file.

Latency measures the average round-trip time (RTT) from when an Interest is sent until the corresponding Data is received:

$$\bar{L} = \frac{1}{M} \sum_{\{i=1\}}^{M} t\_D(i) - t\_I(i))) \tag{2}$$

where, *t_I(i)* is the transmission time of the *i*-th Interest, *t_D(i)* is the reception time of the *i*-th Data, and *M* is the number of valid Interest–Data pairs.

To calculate and generate the latency-related graph, a python-based application was used.

TABLE II. FIRST 10 ENTRIES FROM THE FILE RATE-TRACE.CSV

Time	Node	FaceId	FaceDescr	Type	Packets	Kilobytes	PacketRaw	KilobytesRaw
1	0	1	internal://	InInterests	0	0	0	0
1	0	1	internal://	OutInterests	0	0	0	0
1	0	1	internal://	InData	0	0	0	0
1	0	1	internal://	OutData	0	0	0	0
1	0	1	internal://	InNacks	0	0	0	0
1	0	1	internal://	OutNacks	0	0	0	0
1	0	1	internal://	InSatisfiedInterests	0	0	0	0
1	0	1	internal://	InTimedOutInterests	0	0	0	0
1	0	1	internal://	OutSatisfiedInterests	8.8	0	11	0
1	0	1	internal://	OutTimedOutInterests	0	0	0	0

TABLE III. FIRST 10 ENTRIES FROM THE FILE APP-DELAY-TRACE.CSV

Time	Node	AppId	SeqNo	Type	DelayS	DelayUS	RetxCount	HopCount
0.035343	10	0	1	LastDelay	0.00201	2009.52	1	1
0.035343	10	0	1	FullDelay	0.00201	2009.52	1	1
0.05201	1	0	1	LastDelay	0.00201	2009.52	1	1
0.05201	1	0	1	FullDelay	0.00201	2009.52	1	1
0.068676	35	0	1	LastDelay	0.002009	2009.31	1	1
0.068676	35	0	1	FullDelay	0.002009	2009.31	1	1
0.068676	10	0	2	LastDelay	0.00201	2009.52	1	1
0.068676	10	0	2	FullDelay	0.00201	2009.52	1	1
0.102009	2	0	1	LastDelay	0.002009	2009.41	1	1
0.102009	2	0	1	FullDelay	0.002009	2009.41	1	1

TABLE IV. FIRST 10 ENTRIES FROM THE FILE CS-TRACE.CSV

Time	Node	Type	Packets
1	0	CacheHits	0
1	0	CacheMisses	0
1	1	CacheHits	0
1	1	CacheMisses	0
1	2	CacheHits	0
1	2	CacheMisses	0
1	3	CacheHits	0
1	3	CacheMisses	0
1	4	CacheHits	0

The cs-trace.csv file contains statistics on cache hits and misses for each node, which are used to calculate the Cache Hit Ratio.

First 10 Entries from the File CS-Trace.presents the first 10 entries from the cs-trace.csv file.

CHR represents the proportion of Interests satisfied by intermediate caches rather than by the original producer:

$$CHR = \frac{H}{N_{req}} \tag{3}$$

where, *H* is the number of cache hits and *N_req* is the total number of Interests generated.

The file cs-trace.csv produced output with all recorded values set to zero; therefore, no calculations or graphical visualizations were performed. The reason behind this zero-valued data will be considered as a suggestion for further research.

V. RESULTS AND DISCUSSION

A. Performance of the Proposed Architecture

In the proposed ICN-based NDN architecture for the Aerocity environment, there is a clear alignment between the NDN topology and the data requirements of Aerocity. This alignment is represented by the division into five functional zones—Logistics, Transport, Industrial, Commercial–Residential, and Utilities—each equipped with its own namespace prefixes. For instance, the simulation includes producers with prefixes such as /logistics, /transport, /airport, /industrial, /factory, /commerce, /residential, and /utilities, reflecting the diverse data sources and services required in an Aerocity environment. This mapping illustrates how workloads are semantically organized by namespace, enabling zone-specific routing, caching, and differentiated data handling policies.

Each zone contains multiple edge nodes (ranging from 6 to 10), connected to a dedicated aggregation router that acts as a local gateway. These aggregation routers are then linked to a three-node core backbone (Core A, Core B, and Core C), interconnected with high-capacity links to ensure redundancy and resilience in inter-zone communication. This hierarchical structure mirrors the physical organization of Aerocity networks, where data originates from producers (e.g., cargo systems, traffic management, industrial sensors, multimedia services, and utility monitoring) and is consumed by various applications with different traffic patterns.

The model is explicitly topology-driven, with NDN's forwarding plane components FIB, PIT, and CS configured according to the physical layout. The Content Store (10,000 entries, LRU policy) ensures in-network caching, allowing repeated Interests to be served closer to consumers. The overlay of Interest/Data flows observed in the simulation emphasizes how consumer requests are routed by name, Data packets are returned along the reverse path, and intermediate nodes opportunistically cache the content. This results in a realistic emulation of Aerocity traffic, where Logistics and Transport zones generate frequent updates (high-rate Interests), Industrial zones issue periodic control traffic, and Commercial–Residential and Utilities zones produce bursty and heterogeneous demands.

The research conducted in this study addresses challenges related to mobility, data dissemination, caching, and adaptive routing by fully capturing the multi-zone, cross-domain, and high-mobility characteristics of Aerocity environments. These conditions position this study at an advantage compared to previous research.

Most existing studies focus on optimization components such as forwarding strategies, caching enhancements, or mobility support, typically applied to specific topologies or limited mobility scenarios. Although such works provide valuable insights, their applicability to Aerocity use cases remains limited due to the absence of multi-modal mobility interactions, vehicles, and ground infrastructure, as well as the lack of a comprehensive analysis of heterogeneous producer–consumer communication across functional zones.

B. Quality of Service (QoS) Analysis

The simulation results show that overall network throughput quickly stabilizes after the initial phase. As seen in Overall throughput vs. Timethe throughput rises from about 7.2 Mbps to 10.1 Mbps within the first few seconds and remains steady until the end of the 200-second simulation. This indicates that the NDN forwarding and in-network caching mechanisms effectively utilize network capacity and maintain consistent performance.

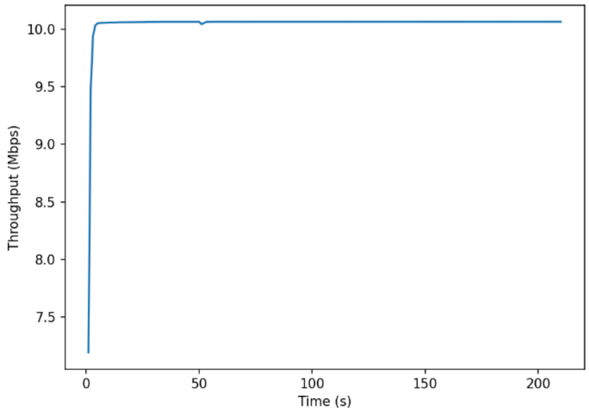

Fig. 3. Overall throughput vs. Time.

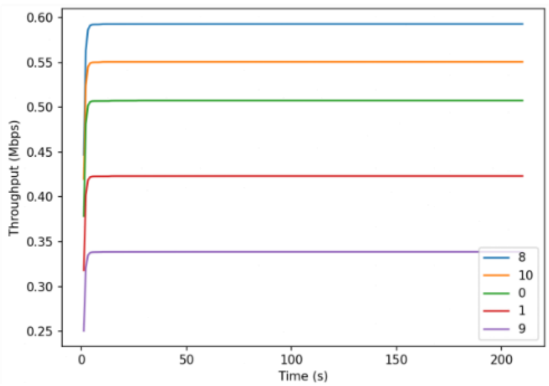

Fig. 4. Throughput vs. Time (top 5 nodes).

Throughput vs. Time (top 5 nodes)highlights the contribution of the five nodes with the highest traffic. Node 8 recorded the highest throughput (0.59 Mbps), followed by Node 10 (0.55 Mbps), Node 0 (0.51 Mbps), Node 1 (0.42 Mbps), and Node 9 (0.34 Mbps). The relatively balanced distribution across nodes suggests that traffic is well distributed, enabling the system to avoid bottlenecks and achieve good load balancing.

The latency analysis confirms that the proposed NDN architecture provides consistently low end-to-end delay. As shown in CDF of application delaymore than 95% of requests are completed within just a few milliseconds, with an overall average delay of about 3 ms.

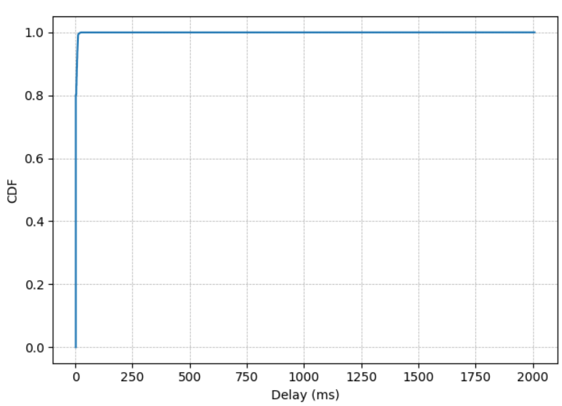

Fig. 5. CDF of application delay.

The graph in Average application delay over timeillustrates the variation of the average application delay throughout the simulation with a 1-second interval. A delay spike of approximately 24 ms is observed at the beginning of the simulation, caused by the initialization process of Interest–Data exchange when the routers have not yet populated their Pending Interest Table (PIT) entries or cached content in the Content Store (CS). After the initial phase, the delay decreases and stabilizes at 2–4 ms, indicating that the in-network caching mechanism is functioning effectively. A minor spike around the 50th second (±9 ms) is likely due to a route change in the Best Route strategy, an Interest burst, or a cache content replacement.

Overall, these results demonstrate that the NDN architecture in the Aerocity topology can maintain low and stable latency after the initialization phase, owing to the efficiency of caching mechanisms and the adaptiveness of the routing strategy. These results demonstrate that the forwarding strategy and in-network caching efficiently sustain low and predictable delay under heterogeneous Aerocity traffic conditions.

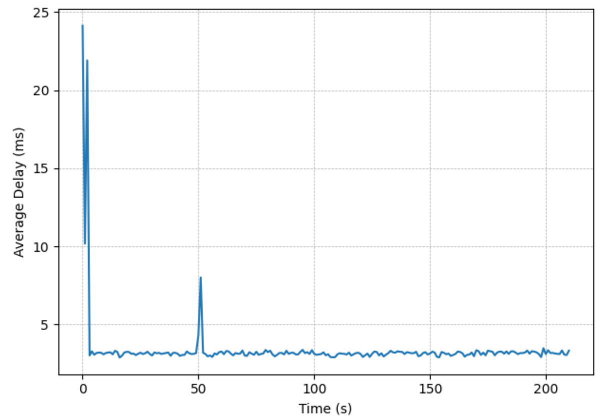

Fig. 6. Average application delay over time.

The Cache Hit Ratio (CHR) is calculated from the number of cache hits and misses recorded in the cs-trace.csv file. However, the simulation output shows that both CacheHits and CacheMisses are zero, making the CHR calculation undefined because the denominator (total requests) is zero. This condition does not necessarily indicate a flaw in the proposed NDN architecture; rather, it is more likely due to limitations in the logging instruments or the Content Store (CS) configuration within ndnSIM, as well as traffic patterns that did not trigger cache reuse. As researchers, it is important to report this condition explicitly to avoid misinterpretation. Therefore, this study focuses on quality of service analysis through throughput and latency metrics, while proposing cache performance evaluation as future work under scenarios with a more active CS configuration or more diverse traffic patterns.

VI. CONCLUSION

This study designed and experimentally evaluated an NDN-based ICN architecture to address heterogeneous communication needs in Aerocity Kertajati. The simulation results show that network throughput quickly stabilized at around 10.1 Mbps (from 7.2 Mbps at the beginning of the simulation), with a balanced distribution across nodes (Node 8 reached 0.59 Mbps, the highest). Latency analysis revealed an average of ~3 ms, p95 < 10 ms, and more than 95% of requests completed within a low-latency bound, despite initial spikes of 20–25 ms. Cache data was unavailable (CacheHits/Misses = 0) due to tracer configuration and traffic patterns that did not trigger cache reuse. Thus, cache analysis is proposed as future work. This study proposes an Information-Centric Networking (ICN) architecture based on Named Data Networking (NDN), specifically tailored to meet the requirements of Aerocity environments, which are characterized by multi-zone structures, cross-domain interactions, and high mobility. The developed architecture integrates adaptive routing mechanisms, a hierarchical naming scheme, and caching strategies to support real-time data exchange across logistics, transportation, industrial, commercial–residential, and utility zones. Through simulations conducted with ndnSIM, the architecture demonstrates performance improvements in latency and throughput, thereby validating its relevance for modern communication scenarios in Aerocity settings.

The main contributions of this research include the introduction of an NDN architecture explicitly designed for Aerocity ecosystems, the development of a reproducible simulation scenario, and the analysis of producer–consumer communication patterns across zones. These findings provide scientific value that strengthens the potential of NDN as a future network architecture for Aerocity environments.

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