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IoT-NDN Devices Through "NDN4IoT" App  
Integrated with FIWARE

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Mohamed Ahmed M. Hail

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# Efficient Management, Control and Analysis of IoT-NDN Devices through "NDN4IoT" App Integrated with FIWARE

Mohamed Ahmed M. Hail  
Institute of Telematics  
University of Lübeck  
Lübeck, Germany  
Email: m.hail@uni-luebeck.de

**Abstract**—The development of mobile applications for IoT systems has become increasingly important due to their ability to provide remote control, monitoring, and efficient analysis of device data for effective device management and decision-making. In recent years, the research on Named Data Networking (NDN) for IoT systems has focused on addressing challenges such as device heterogeneity, network scalability, data privacy, and efficient communication protocols for IoT-NDN devices. This paper presents the design of an app called "NDN4IoT" that enables remote management, control, and observation of IoT devices that utilize NDN technology. The app is integrated with the FIWARE IoT platform, which allows for the retrieval and storage of log information from the IoT-NDN devices. This log information can be used for critical data analysis and decision-making purposes before device failure. The proposed app design provides a user-friendly interface that enables efficient management and monitoring of the IoT-NDN devices remotely. This solution addresses the challenges of managing and controlling IoT devices, specifically those utilizing NDN technology, and enables efficient use of log data for analysis and decision-making purposes.

## I. INTRODUCTION

IoT devices have become ubiquitous in many aspects of modern life, ranging from smart homes to industrial automation systems. However, managing and controlling these devices efficiently can be a challenging task due to their heterogeneity and the need for reliable and secure communication protocols. Named Data Networking (NDN) is a promising communication paradigm that provides efficient data retrieval and caching mechanisms through content-based routing.

FIWARE is an open-source platform that offers a set of standards and APIs for developing IoT applications. It provides a comprehensive set of services for IoT device management, data analysis, and storage, among other functionalities. However, integrating FIWARE with NDN-based IoT systems can be complex due to the differences in communication protocols and data formats.

To address this challenge, we have developed the NDN4IoT app, which integrates FIWARE services with NDN-based IoT systems. The app provides an efficient management and control mechanism for IoT devices by enabling users to control all devices through commands that run on the NDN proto-

col. Furthermore, the app facilitates frequent and/or critical requests made by FIWARE to reduce transmissions by the IoT-NDN network.

This paper provides an overview of the related work in section II. It also includes a brief description of the the IoT-NDN and NFD as well as the FIWARE architecture, covered in section III. Section IV details the design and architecture of the NDN4IoT app and its integration with FIWARE. In section V, we present two scenarios demonstrating the app's ability to manage, control, and analyze IoT-NDN devices. Finally, section VI concludes the paper.

## II. RELATED WORK

NFD has been designed and developed as a forwarder protocol based on NDN, see [1] and [2]. NFD has been also used for applications on different platforms such as Android systems [3].

The authors in [4] describe a distributed mobile health (mHealth) application based NDN to collect and publish data. The idea is to use the NDN network and show differences between NDN and TCP/IP approaches for mHealth. They present and discuss the design and initial implementation of the NDNFit (a mobile fitness tracking application).

An another app over NDN [5] illustrated a real-time smartphone app and shares whiteboard. Using the whiteboard app two users can draw together and share that in real time. The NFD should be installed and run on the phone before the whiteboard app can be used [5].

The project ChronoChat considers a message application for android mobile devices [6]. The communication between the mobile devices is based on NDN and running NFD-Android with WIFI Direct support [7]. The authors evaluate the design and different feature of ChronoChat app considering the aspects of integration NFD to the Android platform. ChronoChat has been compared with the Whiteboard App in [6].

An another interesting project is the Now@ which is developed to synchronization and exchange data based on users interests via NDN architecture [8]. @Now can operate on the top of NFD Android and uses the wireless technology

to exchange the data between intermediate devices [8]. @Now considers Twitter as an use case and allows users subscriptions to multiple namespaces where the users can write posts.

The npChat app is an Android-based photo and file sharing application that draws inspiration from Snapchat [9]. The project aims to develop a fully decentralized application that runs on the Named Data Network (NDN), incorporating a partial sync protocol and a Web-of-Trust model instead of the traditional NDN hierarchical model.

The goal of the approach presented in [10] is to connect and control the Artificial Intelligence (AI) and IoT via smartphone. Any user can manage his house to avoid any considerable damage caused by natural disasters remotely or on site.

### III. IoT-NDN, NFD AND FIWARE ARCHITECTURE

#### A. IoT-NDN

This section provides an overview of the IoT-NDN architecture, which has already been extensively described in [11]. The implementation of IoT-NDN has been discussed in previous research articles such as [12], [13], [14], and [15]. In this section, we will briefly introduce the key components of the IoT-NDN and their functions. Figure 1 provides a visual summary of all the components in the IoT-NDN system.

At the bottom of the IoT-NDN architecture lies the IoT device layer, which encompasses all heterogeneous IoT devices. The top of the IoT-NDN architecture is the IoT applications layer that requests the data. IoT-NDN serves as a networking layer that delivers the requested data from the underlying layer to the overlying layer.

The IoT-NDN architecture comprises three main components: Naming, Data Plane, and the Management and Control Plane. The Naming component consists of a novel naming scheme and structure that is appropriate for constrained wireless network devices. The Management and Control Plane contains subcomponents such as Unicast Faces, Forwarding Services, Intra Node Protocol (INP), Controlled Flooding, Configuration, and Alias Service. The Data Plan component comprises the caching and forwarding strategies of IoT-NDN data. The IoT-NDN components manage IoT-NDN packets, including naming, caching, and strategies in the IoT-NDN system. All the components depicted in Figure 1 are designed, developed, and added to meet the requirements of IoT.

All devices that use the IoT-NDN architecture have three tables: CS, PIT, and FIB. All IoT-NDN packets, including Interest and Data packets, are received and sent through faces. Faces are used in IoT-NDN to simplify the processing and forwarding of messages in the IoT-NDN system concerning the network or local applications. More information about the IoT-NDN components and their functions can be found in [11] and [16]. The implementation of faces in IoT-NDN is also described in detail in [11].

#### B. NDN Forwarding Daemon (NFD)

NFD is a network forwarder developed based on the Named Data Networking (NDN) protocol [2]. It is a free and open-source software package that has become the core component

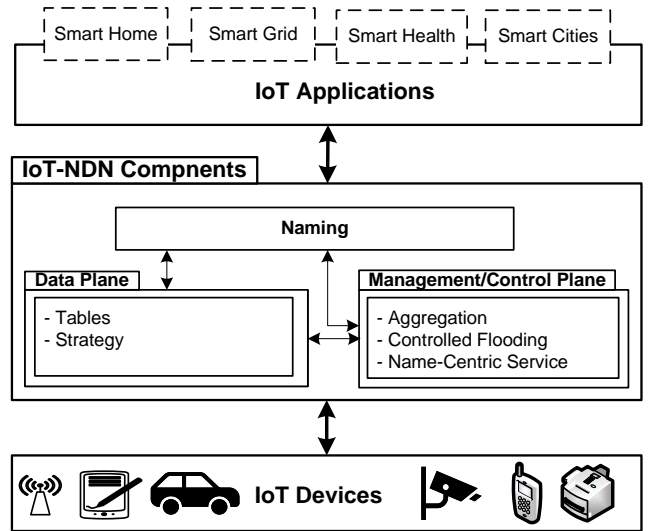


Fig. 1: IoT-NDN System Architecture and its Components

of the NDN platform. The main objective behind designing NFD is to facilitate researchers and developers in conducting experiments with NDN technologies. NFD aims to provide an easy way to test and evaluate new protocols, features, algorithms, and applications. NFD is continually evolving in three areas: improving the modularity framework, keeping up with the NDN protocol specification, and adding new features [2]. Table I displays the significant modules of NFD.

TABLE I: Major Modules of NFD [2]

Modules	Description
<b>Core</b>	Provides various common services shared between different NFD modules.
<b>Faces</b>	Implements the NDN face abstraction on top of different lower level transport mechanisms.
<b>Tables</b>	Implements the CS, the PIT, the FIB, and other data structures to support forwarding of NDN Data and Interest packets.
<b>Forwarding</b>	Implements basic packet processing pathways, which interact with Faces, Tables, and Strategies.
<b>Management</b>	Implements the NFD Management Protocol, which allows applications to configure NFD and set/query NFD's internal states.
<b>RIB Management</b>	Manages the routing information base (RIB)

1) *NFD on Android*: NFD-Android is a specialized version of NFD designed to operate on Android-based smartphones. This customized version employs the WIFI direct module for establishing local networks. Regrettably, information about NFD and NFD-Android is scarce since no publications about either system are currently available.

#### C. FIWARE Architecture

FIWARE is an open-source platform that aims to accelerate the development of smart solutions for various systems and environments, including IoT. It was created in Europe to make the development of smart applications in multiple sectors faster and more accessible. The platform is composed of different

configurable components that can be assembled and operated together to build a platform that supports the development of smart solutions in different branches such as Smart Cities, Smart Industry, Smart Energy, etc.

The Context Broker Generic Enabler is the core component of FIWARE and is responsible for managing context information. It updates and accesses the current state of context and forwards information based on requests or subscriptions. The platform was built by an independent community comprising companies, hubs, and strategic partners. More information about FIWARE and its components can be found in [16] and [17].

#### IV. DESIGN AND ARCHITECTURE

The "NDN4IoT" app is designed to enable efficient management, control, and analysis of IoT-NDN devices remotely. The app's architecture consists of the components shown in Figure 2.

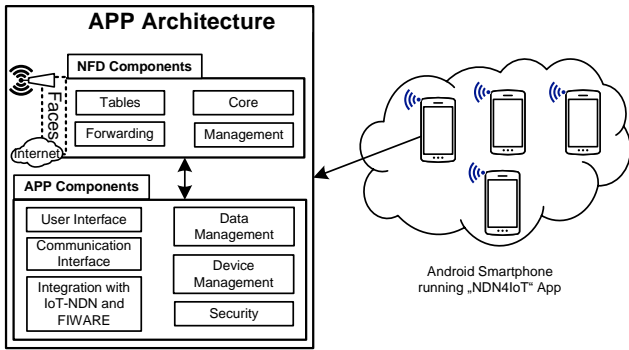


Fig. 2: App Architecture and its Components

- **User Interface:** This component provides a graphical user interface (GUI) for interacting with the IoT-NDN devices. It may include screens for device management, device information display, and system settings.
- **Communication Interface:** This component provides a communication interface between the app and the IoT-NDN as well as the FIWARE devices. It may utilize the NDN protocol for efficient communication with the IoT-NDN for uncritical requests and to FIWARE for critical requests as shown in Figure 3.
- **Device Management:** This component manages the configuration and control of the IoT-NDN devices. It includes features such as device discovery, device pairing, device configuration, and device control.
- **Data Management:** This component manages the data generated by the IoT-NDN devices. It includes features such as data collection, storage, and analysis. It is also responsible for storing log information from the IoT-NDN devices. The app utilizes the FIWARE IoT platform for log storage, which enables efficient data analysis before device failure. The log data can be used to identify patterns and trends in the device's behavior and to predict potential failures.

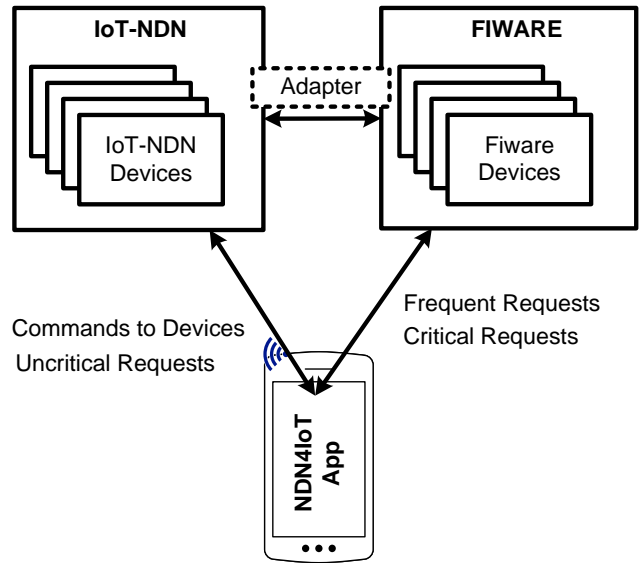


Fig. 3: The App connects to IoT-NDN for uncritical requests and to FIWARE for critical requests

- **Security:** This component ensures the security and privacy of the data transmitted and stored by the IoT-NDN devices. It may include features such as data encryption and access control.
- **Integration with IoT Platforms:** This component integrates the app with IoT platforms such as FIWARE or ThingSpeak, allowing for efficient data storage and analysis.

The "NDN4IoT" app's architecture is designed to be scalable and adaptable to diverse IoT-NDN device configurations. The modular design approach enables the integration of new functionalities and IoT platforms into the app architecture. Overall, the app's design and architecture offer a practical solution for managing, controlling, and analyzing IoT-NDN devices remotely.

#### V. USE CASE AND FUNCTIONALITY

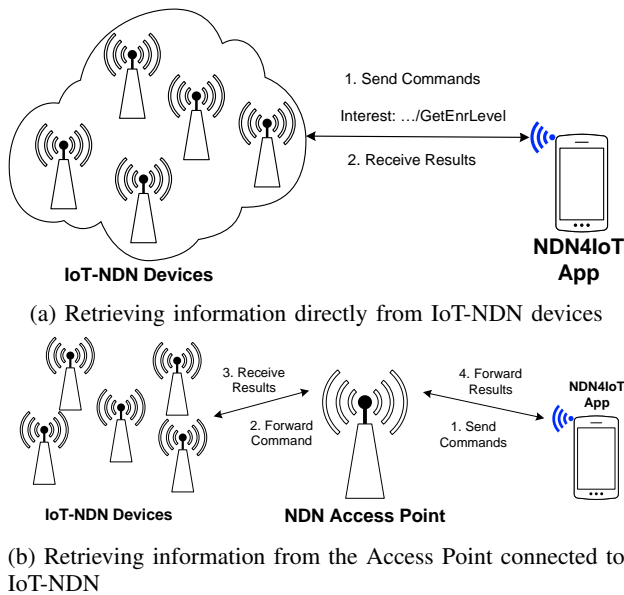
##### A. Retrieval Data form IoT-NDN

After launching the NDN4IoT app, the app uses a ping command (Interest Packet) to discover the neighbor networks based on NDN. The nodes in the network respond with Data Packets. This command can also be sent to a single access point since it has information about all nodes in the IoT-NDN network. This reduces the number of Interest packets sent to the network and saves energy.

Through the app, we can obtain information about device connectivity, energy status, and critical data that are pushed by the device during the connection. Figures 4a and 4b illustrate these scenarios using NDN4IoT.

##### B. Retrieval Critical Data from FIWARE

The second scenario, as shown in Fig. 5, is when the user needs to retrieve log information about devices that have



shut down due to errors or low energy levels. To obtain this information, the user can send an interest packet directly to the FIWARE platform, which stores the log data for all devices integrated with the NDN4IoT app.

Since devices lose their log information upon shutting down, it is essential to retrieve this information from the FIWARE platform. By accessing this information, the user can analyze it and make informed decisions about the errors on IoT-NDN devices.

Retrieving log data from the FIWARE platform also has the added benefit of saving energy on IoT-NDN devices. Since the requests are not forwarded to the network, the devices do not need to handle these requests, thus conserving energy.

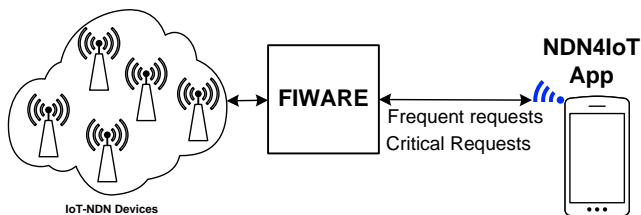


Fig. 5: Directly connecting to the FIWARE Platform for retrieving log information

## VI. CONCLUSION AND FUTURE WORK

In conclusion, the paper presented the design and architecture of "NDN4IoT," an app that efficiently manages, controls, and analyzes IoT-NDN devices. The app's integration with the FIWARE IoT platform allows for remote control, monitoring, and log information retrieval from IoT-NDN devices, leading to improved decision-making and device management. The proposed app architecture addresses the challenges of managing and controlling IoT devices, specifically those utilizing NDN technology. The app's user-friendly interface enables efficient device management and performance monitoring, while

the log information storage facilitates critical data analysis before device failure. Overall, the presented app architecture contributes to the IoT-NDN research field by offering a practical solution to manage, control and analyze IoT-NDN devices remotely. The app's potential applications are vast, including smart homes, healthcare, and industrial systems. The proposed architecture provides a strong foundation for future development and innovation in the IoT-NDN ecosystem.

Future work could explore the integration of additional IoT platforms and protocols into the app architecture to further improve the management, control, and analysis of diverse IoT-NDN devices.

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