Demo: Enabling Autonomic Network Infrastructures with KIRA

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ABSTRACT

Increasing dynamics and an ever growing number of devices make current and future mobile network infrastructures more and more complex. Managing such networks thus becomes progressively challenging. Introducing more autonomic behavior in network management becomes indispensable to not only handle the growing complexity, but also to make these infrastructures more resilient as they constitute a critical component of overall public infrastructures. Autonomic control planes provide a fundamental set of resilient, autonomic infrastructure services (e.g., connectivity) for higher-level autonomic behavior to build upon. In this demo we show how a first real-world implementation of the routing architecture KIRA provides zero-touch control plane connectivity to enable an autonomic 5G network infrastructure. The demonstrator allows an in-depth view of each step in the process of bootstrapping a 5G infrastructure as well as of KIRA's resilience when challenged by failures and dynamics. Based on this autonomic connectivity solution we present our vision of more dynamic and resilient autonomic control networks toward the future design of 6G core networks.

KEYWORDS

Network management, Autonomic networks, Resilience

1 INTRODUCTION

Networking infrastructures are becoming increasingly complex, not only in terms of scale but also in terms of dynamics. This is especially apparent in current 5G and even more so in future 6G infrastructures [4], which feature an ever growing number of infrastructure devices and often consider mobile nodes (e.g., drones or satellites) as part of their core network infrastructure. The increasing scale and dynamics of these network infrastructures challenge traditional approaches for network management and control to accomplish OAM (Operations, Administration, and Maintenance) tasks. With mobile network infrastructures becoming more essential and part of critical infrastructures the resilience of these systems is becoming increasingly important.

The ID-based scalable routing architecture KIRA [2, 3] is an important building block to enable truly autonomic networks since it provides *resilient control plane connectivity* between all nodes in a zero-touch manner. In this demo we present a first real-world implementation of KIRA showing that it supplies robust IPv6 connectivity without any configuration as basis for an autonomic 5G core network. KIRA's built-in Distributed Hash Table (DHT) supports self-organization of the latter so that 5G core functions dynamically register themselves and can be found by others in a distributed manner. The demonstrated scenario shows the deployment, activation, and dynamic operation of a 5G core network without requiring any configuration for its control plane connectivity.

Autonomic network management solutions promise to let networks manage themselves lifting more burden from network operators and also making the network itself more resilient by avoiding configuration failures and manual intervention. Most research in autonomic networking focuses on higher-level autonomic behavior [5] and assumes an already configured and working (control) network infrastructure underneath. There has been much work on automatic orchestration of cloud-native 5G core networks [1, 7], but none of them deal with the necessity for autonomic operation of the actual underlying network connectivity itself that KIRA provides.

2 ENABLING AUTONOMIC 5G

5G core networks possess a multitude of different network functions with many interdependencies and are a prime example for the complexity of current networks. Enabling autonomic 5G network infrastructures needs to consider several aspects, which are also demonstrated.

Creating Control Plane Connectivity. Even before any 5G core network function can run, the underlying network infrastructure needs to be managed and configured so that IP connectivity is working between the core network functions. When starting from "zero", such as a freshly connected network infrastructure at link layer (see fig. 1), many tasks need to be performed until a working 5G network is achieved: IP address allocation and assignment, creation of subnetworks as well as setting up DHCP servers, routers, switches, DNS servers, and so on. Configuration of a routing protocol like OSPF already requires many manual configuration tasks, such as configuring routing areas to ensure scalability. KIRA [3] is a scalable zero-touch routing architecture tailored to provide resilient control plane connectivity. KIRA directly routes on topology-independent NodeIDs that each node randomly generates on startup, so it has a built-in address assignment. It finds routes in the link-layer topology by using a Kademlia-based overlay in the NodeID space. High scalability is achieved by letting each node store *source routes* to only

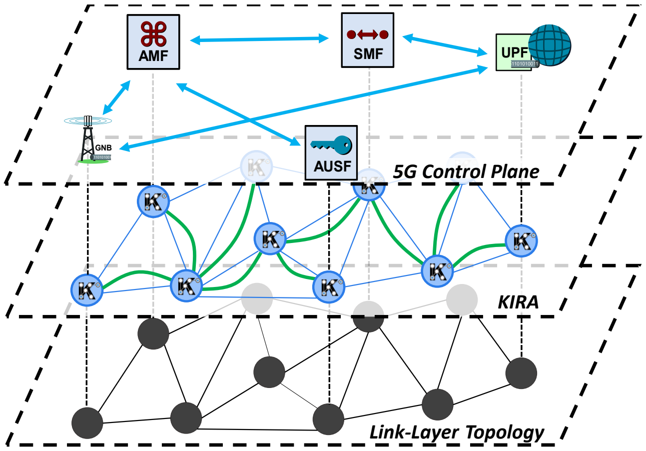

Figure 1: KIRA Integration

a small set of *contact* nodes. Routes to such contacts are converging to shortest paths, whereas routes to other destinations usually incur some stretch. KIRA is loop free even during convergence supporting its robustness during failure situations. After KIRA routing daemons have been started in every node, IPv6 connectivity between all of them is available without any configuration.

Creating an Autonomic 5G Control Plane. Besides basic control plane connectivity, 5G control plane functions also require self-organization for resilience, e.g., dynamic service registration and discovery as well as supporting reorganization after network splits and re-joins. Because NodeIDs are randomly generated, 5G functions should be addressed and discovered by names. KIRA's integrated DHT offers such a simple name registration and lookup service so that 5G core functions can dynamically register and locate each other. This can be viewed as being similar to a distributed realization of the Network Repository Function. Therefore, 5G functions register themselves with their NodeID and function name few seconds after KIRA routing daemons have established connectivity.

Resilient Behavior and Coping with Dynamics. KIRA's ID-based routing easily supports multi-homing and mobility for all 5G functions, i.e., transport connections between the functions remain operational even when nodes move or redundant links fail. Feasible alternative routes are actively discovered in case of link failures. Control plane connectivity adapts quickly to changes of the underlying topology and is upheld if possible. Even during a network split, control plane connectivity inside partitions enables 5G core functions to reorganize themselves so that each partition can work autonomously until the core is merged again. Dynamic addition of nodes and functions will be also demonstrated.

3 DEMO SETUP

We use our demonstrator to show how KIRA's features enable a zero-touch and resilient 5G infrastructure. To do so we emulate small networks running a real world KIRA implementation and a 5G core network on top. Besides showing the bootstrapping process of the control plane connectivity and 5G core, the demonstrator can be used to *interactively* test failure scenarios, e.g., node and

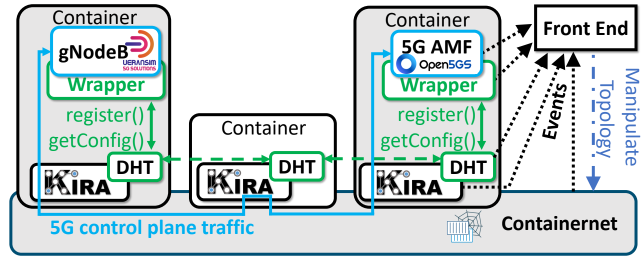

Figure 2: Demonstrator Architecture

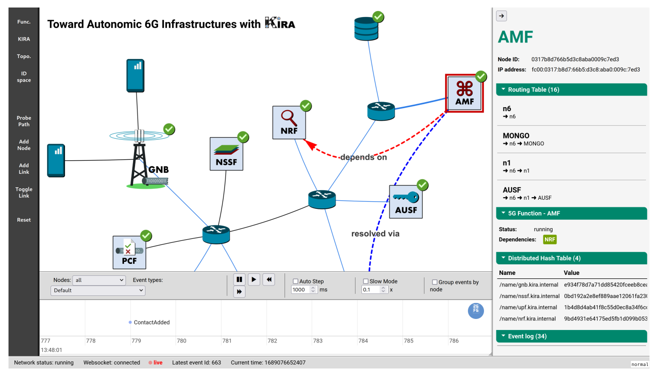

Figure 3: Demonstrator Front-End

link failures, network splits and rejoins and view in detail how KIRA and the 5G network functions react to it. Figure 2 shows the overall demonstrator architecture. It consists of a container-based emulation (Containernet [9]), representing an overall network of interconnected nodes. Each container runs a KIRA routing daemon, providing IPv6 connectivity and some of them additionally run a 5G core network function, e.g., an AMF (open5GS [8]), or a radio tower (gNodeB) with simulated end-systems [6]. Each 5G software component is run in a small wrapper, which loads appropriate configuration values (e.g., IP addresses of dependencies) using KIRA's integrated DHT. As this auto-configuration happens really fast, all important events during the process are recorded and sent to a web-based front-end. The events are sourced from all relevant components: routing updates from the KIRA daemon, requests to the DHT, the loading of configuration values using the wrapper, changes in the physical topology from Containernet and also from the individual 5G network functions themselves. With all of the events aggregated, the front-end then allows to step through each event and view the state of each individual node and the overall network at the time the event was triggered. This allows to follow each step of the bootstrapping process in detail, e.g., how KIRA establishes connectivity in a zero-touch manner and how the 5G network functions find together to form an overall working 5G infrastructure until an end-device can connect to the Internet.

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