Telco-Carrier grade Evaluation of 5G SDN/NFV-enabled Policy Control Concepts

Michael Maruschke
Hochschule für Telekommunikation Leipzig (HfTL)
Leipzig, Germany
e-mail: maruschke@hft-leipzig.de

Jan Kasimir and Manuel Keipert
Telekom Deutschland GmbH
Bonn, Germany
e-mail: jan.kasimir@telekom.de
e-mail: manuel.keipert@telekom.de

***Abstract*—The main question that this paper intends to answer is what telecommunication operators could do for their mobile network evolution until 5th Generation (5G) mobile networks are deployed for mass-market and beyond 2020. Especially in scope is policy-related functionality in the core network. The roadmap for mobile networks should take into account technologies such as Software Defined Networks (SDN) and Network Function Virtualization (NFV) but also consider commercial necessities. This paper examines five approaches proposed by the authors, covering the full range from extending the policy controller's capabilities to removing as many elements of the policy framework as possible. Approaches are rated through evaluation criteria chosen by the authors to create a transparent, objective and Telco-Carrier grade feasible conclusion. The conclusion gives operators possibilities for their strategic roadmap towards 5G networks and support any upcoming design decisions.**

Keywords-5G; NFV; PCF; QoS; SDN

I. INTRODUCTION

With the advent of 5G, SDN and NFV, the motivation for a Telco-Carrier to evaluate policy control concepts is paramount for strategic cost and architecture resource planning. However, up to the present, there is no SDN- and NFV-enabled 5G network available for a Telco-Carrier grade deployment of large scale mass-market production.

In infrastructure-owning operators' cellular mobile networks, the policy controller is an essential function. It provides sophisticated policy handling to ensure service quality and charging [1]. It is also required to realize public voice telephony services in packet-switched networks like Voice over LTE (VoLTE) [2]. The policy controller is part of the comprehensive Policy & Charging Control (PCC) framework, consisting also of policy enforcement functions.

The PCC framework in the cellular mobile packet network will undergo significant changes in multiple dimensions with the transition to 5G networks. Until 5G is available and deployed on a large scale, many other technologies impact policy evolution such as SDN and NFV. The complete core network infrastructure is impacted by the emergence of SDN, NFV and 5G. All three technology trends influence different layers of the Telco operator production network, comprising network layer SDN, system virtualization and 'cloudification' NFV up to the 5G application layer.

Beside those big trends, there are many other aspects directly impacting the policy controller. Accordingly, there are use cases (e.g., full flat rate or Internet of Things (IoT) based), where dynamic policy control will be dispensable.

Telco operators are constantly adapting their network strategy to keep up, firstly with a fast-growing number of terminal devices of all kind (Smartphones, tablets, IoT devices, autonomous driving vehicles, etc.), secondly with the rapidly increasing mobile data traffic those devices produce and thirdly with the complexity increases due to new services. Mobile data traffic grew tremendously in the last few years and forecasts indicate that this trend will continue in the future [3]. The diversity of terminals and use cases that will come with IoT and 5G will put even more demanding requirements on the Telco network infrastructure, for example in terms of latency, bandwidth and other Quality of Service (QoS) related parameters [4]. The PCC framework is key for dynamic QoS policing.

With regards to the PCC framework that provides data charging, VoLTE enablement and QoS handling for data sessions, the evolution towards a 5G network implies many challenges. The diversity of use cases and its usage patterns changes profoundly from 4th Generation (4G) to 5G networks [4]:

- QoS functionalities will be refined to fulfill stringent 5G use case and become highly adaptive (dynamic real-time adapting).
- Other new use cases like Vehicular-to-Everything (V2X) and IoT might not require a dynamic policy controller at all. This QoS-related challenge in 5G of predictable end-to-end (E2E) latency of a few milliseconds might not utilize a centralized Policy & Charging Rules Function (PCRF) in the mobile core network.
- Static versus dynamic rule assignment in 5G will depend on the use case. Static rule assignment bears cost-saving potential as no full-fledged PCRF is required.
- Decentralization of control functions to the core edge (assuming that this is possible) enables the network to cope with strict latency requirements.

 ISBN: 978-1-61208-633-0

In the process of SDN/NFV-based 5G network transformation, there are opportunities for architecture design improvement that have been identified by the authors. This paper presents five approaches that propose adaptations to the Policy Control Function (PCF) – the policy controller in 5G.

In section II, related work and a standardized context of basic architectures for the 5G network, SDN and NFV are introduced. Section III covers the descriptions of the five approaches. In section IV the approaches are evaluated and compared, resulting in our recommendations for Telco operators as to how to include these into their roadmaps. Section V concludes with a summary of the next steps towards 5G for Telco operators.

II. RELATED WORK

A. Research Contributions

In 2015, an academic study was focusing on a fair QoS resource reservation concept for upcoming 5G networks [5]. Nevertheless, this work was not integrated into the 3GPP 5G specifications.

Two more recent contributions address the issue of resource allocation for a key element of 5G networks, the network slices. One paper introduces three new network functions to analyze traffic per network slice, to manage the access rights on network slice resources, and to provide an adaptive traffic forecast model [6]. The other paper presents a model to orchestrate slices based on typical service demands considering the underlying resource capacities [7]. Both research papers relate to optimization of network slice resource usage. Nevertheless, those are pure simulations or calculations that were not verified under real Telco-Carrier network conditions. Furthermore, all three contributions do not address the functional core network nodes that are introduced with 5G, e.g. PCF or User Plane Function (UPF).

B. 5G/SDN/NFV Reference Architectures

The approaches - presented in section III - are based upon 5G/SDN/NFV architectures. For a better understanding, these basic architecture designs are presented in this section.

With regards to 5G, the 3GPP Release 15 proposed system architecture in a domestic scenario is used [8]. Figure 1 shows this 3GPP 5G architecture with service-based interfaces within the control plane.

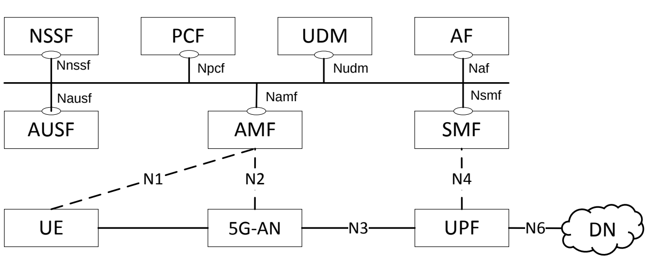

Figure 1: Service-based 3GPP 5G Architecture (cf. [8])

Besides other logical network functions, the control plane includes the PCF and the Session Management Function (SMF). The SMF operates as centralized element between logical control plane network functions and the UPF via interface N4.

A high-level SDN architecture, taken from the ITU-T Recommendation Y.3300 [9], is shown in Figure 2. Stimulated from SDN applications, the centralized SDN controller manages the local existing network devices (in the SDN Resource Layer).

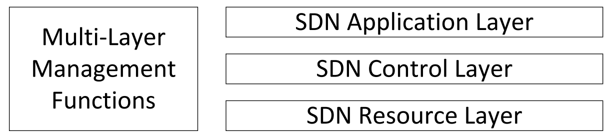

Figure 2: SDN Architecture in three Layers (cf. [9])

To operate and provide a NFV environment with all required configurations, a Management and Orchestration (MANO) framework is specified. The European Telecommunications Standards Institute (ETSI) determined a high-level functional architectural framework for NFV and MANO [10].

Figure 3 displays the ETSI NFV MANO architecture comprising the three functional nodes NFV Orchestrator (NFVO), VNF Manager (VNFM) and Virtualized Infrastructure Manager (VIM).

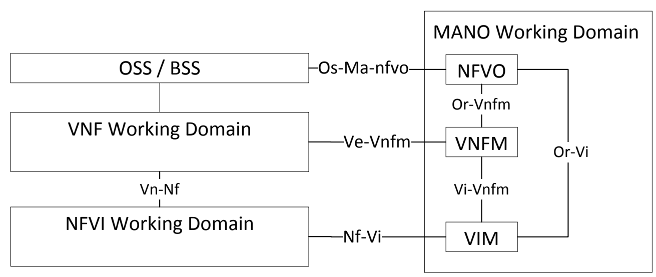

Figure 3: NFV MANO Architecture (cf. [10])

III. PCC APPROACHES

The goal of all approaches is to either extend the policy controller's capabilities to improve the network, or remove as many elements of the policy framework as possible in order to reduce complexity and costs.

A. SMF-integrated PCF

In this approach, the PCF is integrated into the SMF to optimize the logical infrastructure. The resulting architecture is depicted in Figure 4 that shows an SMF with policy control functionalities.

The resulting architecture is more compact. The extended SMF (enhanced with PCF) unites session management functions (manage session establishment, modification and release; control Internet Protocol (IP) address allocation; advice policy enforcement in UPF) and the policy management (evaluate policy decisions).

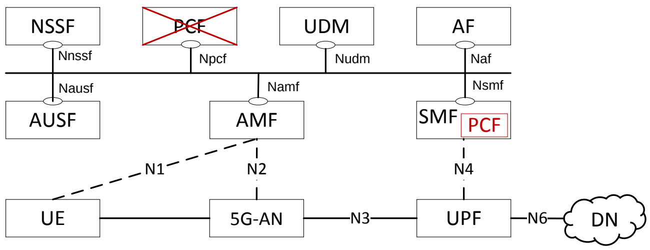

Figure 4: Overview for SMF-integrated PCF Approach

The service-based interface Npcf between a separated PCF and SMF can be omitted. Interactions between PCF and other required functionalities (e.g. Application Function (AF), Unified Data Management (UDM)) corresponding to the 3GPP TS 23.503 (section 5.3) [11] will be realized via SMF.

B. SDN-based PCF

In this approach, a new interface between SMF and SDN controller is introduced exchanging information between PCF and SDN controller over SMF. This enables the SDN controller to decide whether and how to include such information into its transport network steering process.

The precondition is that the mobile core network is deployed on top of an SDN-controlled network infrastructure.

As it can be seen from Figure 5, mobile core network functions operate on the application layer from an SDN architectural point of view. The SDN controller processes information provided by SMF. The decision for a SMF (and not PCF) to SDN controller interface is justified through the SMF's holistic view of the data sessions. The SDN controller steers the network device in the resource layer. Management functions are outlined on the left side of the figure.

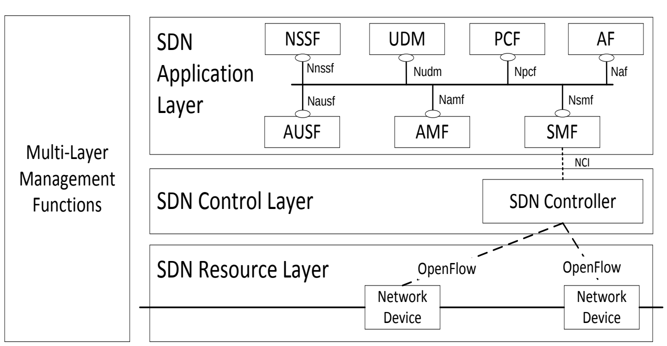

Figure 5: Overview for SDN-based PCF Approach

The SMF delivers session/subscriber related information from PCF via the SDN controller's Northbound Controller Interface (NCI). On this way, the SDN controller becomes service aware and is enabled to adapt the underlying transport layer forwarding path and capacity for a data flow according to a service's requirements, e.g., latency and QoS.

C. Slice-specific PCF

This approach proposes multiple instances of slice-specific PCFs (sPCF). The sPCFs are responsible for one single slice, tailored to serve the slice-specific use cases.

The precondition for this approach is Network Slicing. When a subscriber establishes a new session, the Network Slice Selection Function (NSSF) assigns the session to a slice. A common PCF (cPCF) is deployed in a common domain and coordinates policy management. It is connected to the NSSF and provides relevant information to the slice that is in charge of the subscriber.

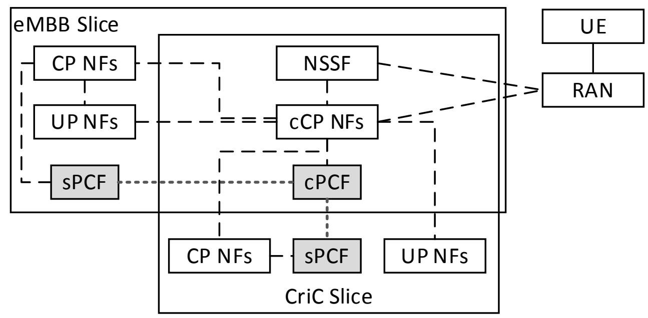

Figure 6: Overview for Slice-specific PCF Approach
(cf. [12] figure 6.1.1.1)

Figure 6 shows an operator's mobile core network with two slices and one common domain in the middle – the area where the two slices overlap (cf. [12] figure 6.1.1.1) . Both slices, enhanced Mobile Broadband (eMBB) and Critical Communications (CriC), have their own sPCF that is connected to the cPCF in the common domain. Other common Control Plane Network Functions (cCP NFs) can be found in the common domain. Furthermore, there are dedicated Control and User Plane Network Functions (CP NFs and UP NFs) in each specific slice. The cPCF is approached first when a customer session establishment request is sent. It is connected to all sPCFs via an interface and forwards the request to the most suitable sPCF instance in a slice. The Radio Access Network (RAN) is informed about the chosen slice and forwards subsequent control and user plane traffic directly to the slice's functions.

D. PCF-based NFV orchestration

In this approach, a virtualized PCF is connected to the VNFM function in the NFV MANO working domain, depicted in Figure 7.

A precondition is that the 5G reference architecture is virtualized in an NFV environment. PCF and other network functions are deployed as VNFs.

The virtualized PCF delivers aggregated application layer information about subscribers, services used, etc., in real-time via Operations Support Systems/ Business System Support (OSS/BSS) layer and NFVO to VNFM for a more accurate VNF lifecycle management and monitoring purposes.

 ISBN: 978-1-61208-633-0

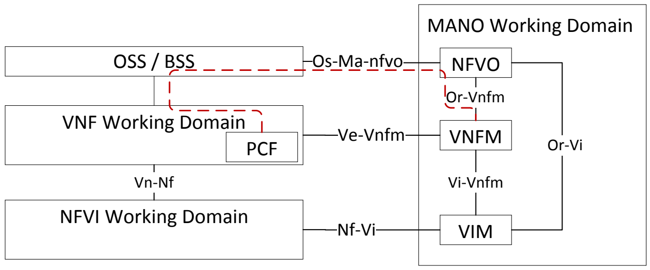

Figure 7: Overview for Virtualized PCF Approach in NFV MANO

PCF can provide, for example, the type of device, type of service or device location. Such information allows the VNFM to handle VNF lifecycle management (VNF instantiation, scaling and termination) more accurately with regards to the demand, quality requirements, and so forth.

E. Obsolete PCF

There are multiple use cases already today and there will be even more in the future that do not require a PCF. Typically, operators aim for network simplicity, hence in today's network the PCRF often controls all mass market subscribers. This approach recommends not applying (dynamic) policy control for some new IoT and 5G use cases as well as existing use cases where dynamic PCC is not needed. Hence a valid strategy option is to remove customers and use cases from the PCF.

IV. Approach Evaluation

Several evaluation criteria have been created, particularly from an infrastructure-owning Telco-Carrier perspective. The criteria are a mixture of standard conformity and technical design aspects, as well as commercial considerations.

A summary of the evaluation of our five PCC approaches is presented in a table.

Finally, the approach rating is illustrated more detailed.

A. Definition of Evaluation Criteria

1) Standards Developing Organization (SDO) conformity (SDO conf.)

This criterion verifies the conformity with regards to the existing technical standards (e.g., 3GPP specifications).

2) Pre-5G compliance (Pre-5G)

This criterion evaluates whether an approach could be implemented in a 4G network.

3) Complexity of Integration and Operation (Compl.)

This criterion evaluates the complexity of the technical implementation and operation for the approach.

4) Cost (Cost)

This criterion estimates the incurred costs for the approach. It excludes any costs for SDN and NFV. Here we assume that costs include Capital Expenditure (CAPEX) and Operational Expenditure (OPEX).

5) Consumer Business Opportunities (Business)

This criterion estimates if new business opportunities are generated by this approach, with regards to additional revenue.

B. Summary of the Evaluation

Table 1 presents our approach evaluation summary. The evaluation is done via a three-tier scale. The scale is defined as follows:

- the approach has a positive effect with regards to the evaluation criterion: '+'
- the approach has a neutral influence with regards to the evaluation criterion: 'o'
- the approach has a negative effect with regards to the evaluation criterion: '-'.

TABLE 1: APPROACH EVALUATION SUMMARY

Evaluation criteria	Approaches				
	SMF-integrated PCF	SDN-based PCF	Slice-specific PCF	PCF-based NFV orchestration	Obsolete PCF
SDO conformity	o	+	+	+	-
Pre-5G-compliance	-	+	+	+	+
Complexity of Integration and Operation	-	o	o	o	+
Costs	+	o	-	-	+
Consumer Business Opportunities	o	+	+	o	-

C. PCC Approach Rating

1) SMF-integrated PCF

The approach centralizes policy and session management in one network node and it is assessed by the evaluation criteria as follows:

a) *SDO conf.: PCF interactions with other control plane functions (e.g., UDM) will be integrated into SMF*

b) *Pre-5G: Evolved Packet Core (EPC) point-to-point interface design causes unmanagable complexity*

c) *Compl.: shared PCF/SMF interface complicates maintainability*

d) *Cost: no additional operational costs for dedicated PCF; further savings through licensing cost reduction*

e) *Business: no new business opportunity, but existing use cases remain*

2) SDN-based PCF

The approach enables mobile data session information exchange to an SDN controller and it is assessed by the evaluation criteria as follows:

a) *SDO conf.: no fundamental change in design principles*

b) *Pre-5G: only requirement is the deployment of a SDN*

c) *Compl.: complication through NCI design & integration effort*

d) *Cost: minor interface design and integration costs*

e) *Business: new service quality enforcement options on network layer, although not visible to end customer*

3) Slice-specific PCF

The approach decentralizes policy control functionality and it is assessed by the evaluation criteria as follows:

a) *SDO conf.: no fundamental change in design principles*

b) *Pre-5G: requirements are deployment of NFV and Network Slicing*

c) *Compl.: decentralization facilitates PCF with reduced functionality, but interactions between PCFs drives complexity*

d) *Cost: increase due to acquisition and operation for multiple PCF nodes*

e) *Business: offer services for diverse use cases in dedicated independent slices*

4) PCF-based NFV orchestration

The approach improves NFV MANO processes and it is assessed by the evaluation criteria as follows:

a) *SDO conf.: no change in design principles*

b) *Pre-5G: only requirement is the deployment of a NFV*

c) *Compl.: complication through new interface design & integration effort*

d) *Cost: minor interface design and integration costs; MANO function enhancement to incorporate interface*

e) *Business: no new business opportunity, but existing use cases remain*

5) Obsolete PCF

The approach reduces complexity in the mobile core network and it is assessed by the evaluation criteria as follows:

a) *SDO conf.: PCF removal is not foreseen by 3GPP*

b) *Pre-5G: same constraint as for 5G, namely no more dynamic policy handling*

c) *Compl.: no PCF node and streamlining of use cases*

d) *Cost: neither licensing nor operational costs for PCF*

e) *Business: reduction of feasible use cases*

V. CONCLUSION

The best improvement for the pre-5G and 5G architecture in the authors' view is a combination of the approaches depending on the use cases. This is most easily done in a sliceable, virtualized and programmable core network, which is expected to be built in the near future to be prepared for 5G.

A. Combining Approaches

In 5G, the recommended basic setup is to have one slice per 3GPP use case category [13]: eMBB, CriC, Massive Machine Type Communications (mMTC), Enhancement of Vehicle-to-Everything (eV2X).

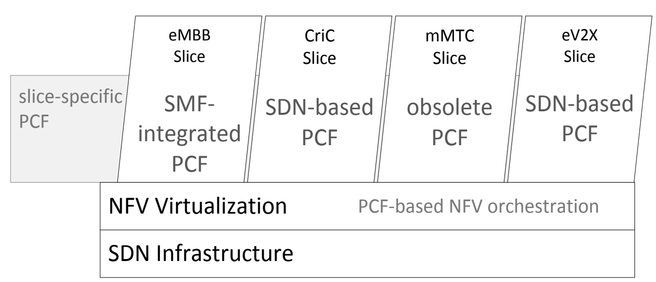

Figure 8: Combining Approaches

Figure 8 constitutes a sliced operator network on top of an NFV-virtualized and SDN-controlled infrastructure, where all approaches are implemented. The slice-specific PCF approach is implemented implicitly, as Network Slicing is employed and multiple PCFs are used. The PCF-based NFV orchestration approach is also implied as each slice

PCF can integrate the interface to VNFM if required. For each slice, there is one approach applied:

a) eMBB slice

Operates conventional mobile data use cases (that require high bandwidth) and VoLTE. The SMF-integrated PCF approach is advisable here, especially with respect to VoLTE.

b) CriC slice

Use cases in this category are for example factory automation and telemedicine. Low latency and high availability is essential to such critical communication. The network can support fulfillment of such demands through optimized routing with the help of an SDN. Applying the SDN-based PCF approach further improves the route optimization process of the SDN controller.

c) mMTC slice

The focus in this slice lies on IoT use cases that need high resource and energy efficiency. Wearables, sensors and other IoT devices rely on a long-lasting power supply and transmit typically very small data. Dynamic policy rule evaluation is not required; hence the obsolete PCF approach is recommended to reduce complexity, latency and save money.

d) eV2X slice

Use cases demands are similar to CriC use case demands (low latency and high availability) plus safety aspects and positioning accuracy. Therefore, the SDN-based PCF approach is a suitable option.

B. Final considerations

It should be stated that there is no 'one-size-fits-all approach' that is equally suitable for all types of operators. Moreover, there is no single approach for an operator but always a well-balanced mixture to bridge the time between 4G deployments and future SDN and NFV based 5G networks. Operators are diverse in terms of technical, infrastructural and financial aspects as well as service offerings, market position, etc. Those aspects matter as these drive the complexity of the network, which makes it usually difficult for big infrastructure-owning Telco-Carriers to adapt. All results and recommendations must be interpreted by the operators. Combining these approaches to the operators needs provide a real benefit partially already now as well as for sure with 5G based on the flexibility of a SDN/NFV Telco cloud.

Beside these overarching strategic results, the paper proposes five PCC approaches for network enabling and significant cost cutting.

This paper is intended to allow the operator to adapt the 3GPP 5G reference architecture to meet its carrier-specific needs and network strategy. Nevertheless, for each operator the challenge remains to develop its real deployed carrier networks and processes towards a 5G-enabled policy control based network.

REFERENCES

[1] 3GPP, TS 23.203 - Policy and Charging Control Architecture (Release 15) V15.2.0 (2018-03).

[2] GSM Association, Official Document IR.92 - IMS Profile for Voice and SMS V11.0, 2017. Available: https://www.gsma.com/newsroom/wp-content/uploads//IR.92-v11.0.pdf.

[3] Ericsson, June 2017. [Online]. Available: https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf.

[4] 3GPP, TS 22.261 - Service requirements for the 5G system V16.2.0 (2017-12).

[5] R. Trivisonno, R. Guerzoni, I. Vaishnavi und A. Frimpong, „Network Resource Management and QoS in SDN-Enabled 5G Systems," 2015 IEEE GLOBECOM , Dec. 2015, ISBN: 978-1-4673-9526-7.

[6] V. Sciancalepore, K. Samdanis, X. Costa-Perez, D. Bega, M. Gramaglia und A. Banchs, „Mobile Traffic Forecasting for Maximizing 5G Network Slicing Resource Utilization," IEEE Conference on Computer Communications (INFOCOM 2017), May 2017, ISBN: 978-1-5090-5336-0.

[7] D. T. Hoang, D. Niyato, P. Wang, A. De Domenico und E. Calvanese Strinati, „Optimal Cross Slice Orchestration for 5G Mobile Services," 16 December 2017. submitted [Online]. Available: https://arxiv.org/abs/1712.05912.

[8] 3GPP, TS 23.501 - System Architecture for the 5G System (Release 15) V15.0.0 (2017-12).

[9] ITU-T, Recommendation Y.3300 - Framework of software-defined networking, (06/2014).

[10] ETSI, GS NFV-MAN 001 – Network Functions Virtualization (NFV); Management and Orchestration v1.1.1, (2014-12) .

[11] 3GPP, TS 23.503 - Policy and Charging Control Framework for the 5G System (Release 15) V15.0.0 (2017-12).

[12] 3GPP, TR 23.799 - Study on Architecture for Next Generation System (Release 14) V14.0.0 (2016-12).

[13] 3GPP, TR 22.891 - Feasibility Study on New Services and Markets Technology Enablers (Release 14) V14.2.0 (2016-09).

 ISBN: 978-1-61208-633-0