Analysing the Transmission of Warning Message in the Web-Based Applications

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ABSTRACT: *In the fifth generation mobile network system, various performance requirements are demanding. To institute the service delivery, it should be service oriented. This research improves the protocol style interface between radio access and web-based application programming interfaces. In the service oriented architecture, the functions of next generation application protocol are equated to the warning message transmission which is reflected as service and help more flexible deployment. The issue is about the warning message transmission which is really a service. We considered the service description and the implementation aspects.*

Keywords: 5G, Service Oriented Architecture, Radio Access Network, Representational State Transfer

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1. Introduction

Fifth generation (5G) mobile networks will provide three types of services:

• Enhanced Mobile Broadband (eMBB) with requirements of high bandwidth, indoor/hotspot and enhanced wide area coverage;

• Ultra-Reliable and Low Latency Communications (URLLC) with requirements of very low user plane latency, very high reliability and availability, and high mobility;

• Massive Machine Type Communications (mMTC) characterized by high device density and requirements for low power consumption.

In order to support the very wide range of services with diverse requirements, the 5G network architecture has to be flexible, modular and scalable, and has to support high level of programmability and automation in networks [1], [2]. Following this design principles, the 5G core network is centered around services accessible through Application Programming Interfaces (APIs). Service Oriented Architecture enables greater functional and service agility, as the introduction of new service or upgrade of existing one becomes simpler and facilitates the transition to the cloud model [3].

The concept of Every-Thing-as-a-Service is introduced in [4]. The authors argue that every component which used to be essential in the traditional network management including Radio Access Network (RAN) can be viewed as a service. In [5], a service oriented framework for RAN sharing is proposed. The aim is to facilitate radio resource sharing between different mobile operators. Adoption of service-based design facilitates slicing and orchestration of RAN [6].

In this paper, following the service-oriented design of 5G core network, we propose an approach to transition to servicebased architecture adopted for the core network of RAN. The control protocol between the Next Generation RAN (NGRAN) and the core network is Next Generation Application Protocol (NGAP) [7]. In our approach, NGAP functions are defined as services following modular function design. The focus is on warning message transmission function, which enables sending messages from the network to mobile subscribers.

The rest of the paper is organized as follows. Next section describes the functionality of the proposed service illustrated with typical use cases. Section III presents the API definition. Section IV considers some implementation aspects regarding modeling of service logic as seen by the core network and RAN. The conclusion summarizes the contribution.

2. Service Description

The proposed Warning Message Transmission Service (WMTS) exposes functionality of Warning Message Transmission Procedures of NGAP protocol. It may be used to send local content, service context, and real-time information on local access network conditions. The service supports write-replace warning, cancel, reloading of Public Warning System Message (PWS) broadcast, and PWS failure indication. The interaction between WMTS and the core network services follows the REpresentational State Transfer (REST) architectural style. In REST, each entity is represented as a resource. The resource is characterized by its state which can be manipulated by four operations implemented by HTTP requests, namely: CREATE (HTTP POST), READ (HTTP GET), UPDATE (HTTP PUT), and DELETE (HTTP DELETE).

The purpose of write-replace warning procedure is to start or overwrite the broadcasting of warning messages. It is initiated by Access and mobility Management Function (AMF) in the core network. When the AMF wants to start broadcasting of warning messages, it sends a POST request to the resource representing warning messages. The message body contains the content to be broadcasted, the repetition period, and the broadcast area. The NG-RAN node schedules a broadcast of the warning message and starts broadcasting. It acknowledges the request by sending “201 Created” message to the AMF. The message contains the URI (Uniform Resource Identifier) of the resource created. Figure 1 shows the procedure.

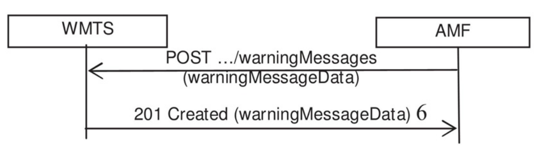

Figure 1. Flow of warning message broadcasting initiation

The purpose of the PWS cancel procedure is to cancel an already ongoing broadcast of a warning message. When the AMF wants to cancel the procedure it sends DELETE request to the resource representing the respective warning message. The NG-RAN node, in turn, stops broadcasting the warning message within that area and discards the warning message for that area, if the broadcasting area is included, or in all of the cells. The WMTS acknowledges the request by sending “204 No Content” response. Figure 2 shows the procedure.

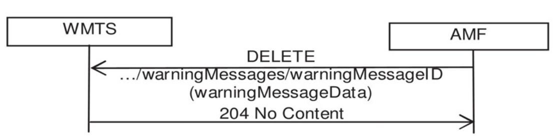

Figure 2. Flow of warning message broadcasting cancelation

The purpose of the PWS Failure Indication procedure is to inform the AMF that ongoing PWS operation for one or more cells of the NG-RAN node has failed. The purpose of the PWS restart indication procedure is to inform the AMF that PWS information for some or all cells of the NG-RAN node may be reloaded from the Cell Broadcast Center if needed. In order to receive indications, the AMF needs to make a subscription. When the AMF wants to receive PWS related indications it sends a POST request with the message body containing *wmSubscriptionData* data structure to the resource representing the respective subscription type. The subscription types may be one of the following: the *pwsFailureSubscriptions* type and *pwsRestartSubscriptions* type. The *wmSubscriptionData* data structure defines the event subscription, filtering criteria and the address where the AMF wants to receive indications. The WMTS sends "201 Created" response with the message body containing the address of the resource created and the subscribed PWS restart indication event subscription type. The above is illustrated in Figure 3.

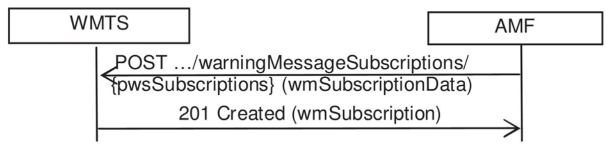

Figure 3. Flow of subscription for PWS related indications

The WMTS may define an expiry time for the PWS restart indication subscription, which is included in the response of subscription request. When subscription expiry time is used, prior the subscription expiry, the WMTS may notify the AMF, which in turn needs to update the subscription. The AMF updates the subscription by sending PUT request to the resource representing the respective subscription type with modified data structure specific to that PWS restart indication event subscription, as shown in Figure 4.

When the AMF does not want to receive indications about PWS broadcast related events anymore, it terminates the subscription. Figure 5 shows a scenario where the AMF uses REST based procedure to delete the subscription for indications about PWS broadcast indications.

Figure 4. Flow of subscription update for PWS related indications

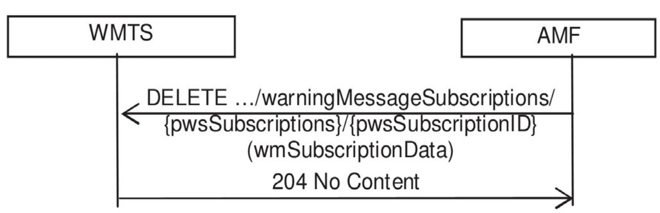

Figure 5. Flow of PWS restart indication subscription termination

When the NG-RAN node detects that ongoing PWS operation has failed for one or more cells, it sends a notification to inform the AMF. Figure 6 illustrates the scenario.

When the NG-RAN node detects that a PWS information for some or all cells may be reloaded from the Cell Broadcast Centre, the WMTS sends an indication to the AMF. Figure 7 illustrates the case.

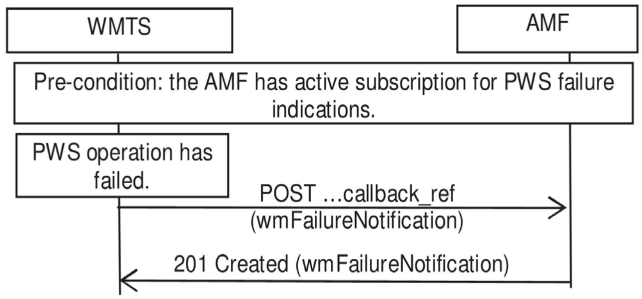

Figure 6. Flow of receiving indications about PWS failure

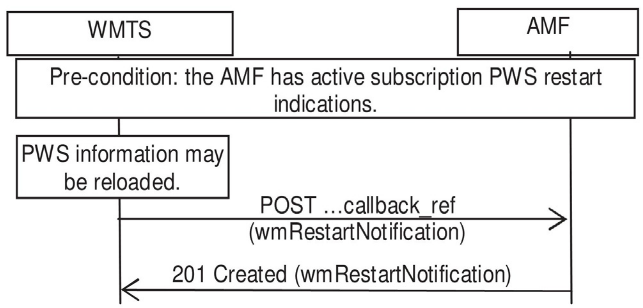

Figure 7. Flow of receiving PWS restart indications

Summarizing the WMTS use cases the following service operations may be defined:

• send_warning_message – the AMF invokes this operation to start broadcasting of warning message;

• cancel_warning_message – the AMF uses this operation to cancel the warning message broadcasting;

• start_pws_failure_indications and start_pws_restart_indications – the AMF uses these operations to create subscriptions for PWS failure and PWS restart indications respectively;

• stop_pws_failure_indications and stop_pws_restart_indications – the AMF uses these operations to terminate the subscriptions for PWS failure and PWS restart indications respectively;

• update_pws_failure_indications and update_pws_restart_indications – the AMF uses these operations to update the subscriptions for PWS failure and PWS restart indications respectively;

• notify_pws_failure and notify_pws_restart – the WMTS uses these operations to send notification about PSW failure and PSW restart respectively.

3. Interface Definition

Figure 8 presents the resource structure. All service resources have the following root: {apiRoot}/wmts/{apiVersion}/

The container resources warningMessages, warningMessage-Subscriptions, pwsFailureSubscriptions and pwsRestartSubscriptions support HTTP GET method which retrieves information about the resource, and HTTP POST method, which creates a new resource of the respective type. The leaf resources warningMessageID, pwsFailureSubscriptionID, and pwsRestart- SubscriptionID support HTTP GET the message method which retrieves information about existing resource, HTTP PUT method which updates information about existing resource, and HTTP DELETE method which deletes the existing resource.

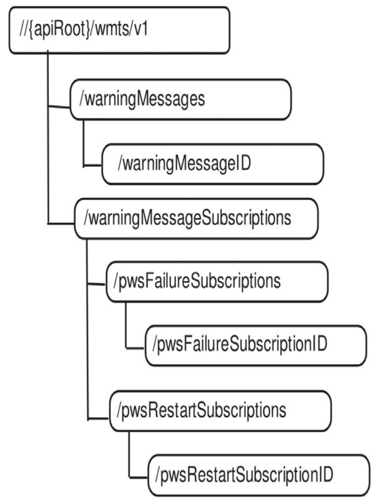

Figure 8. Structure of resources supported by WMTS

4. State Models

Deployment of WMTS in the network requires development of models, representing the warning message broadcast status as seen by the NG-RAN node and by AMF. Both models need to be synchronized.

Figure 9 shows the simplified model of the warning message broadcast status as seen by the AMF. In Broadcasted state, the warning message is broadcasted successfully or there is no warning message to be broadcasted. In Broadcasting state, the warning message broadcasting is ongoing. In PwsFailure state, the AMF has received a PWS failure indication.

Figure 10 shows a simplified model representing the warning message broadcast status supported by the NG-RAN node. In order to broadcast a warning message, the NG-RAN node needs to establish appropriate radio bearers. The purpose of Radio Resource Control (RRC) Reconfiguration procedure is to modify an RRC connection, e.g. to establish/modify/release radio bearers [8].

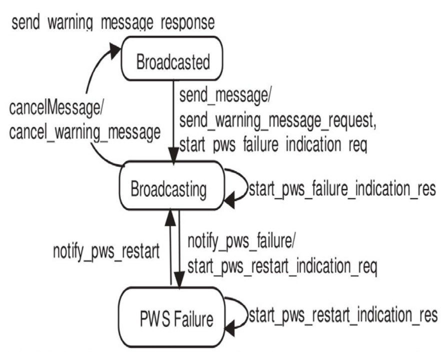

Figure 9. Model of warning message broadcast status, supported by AMF

In order to provide a more rigorous proof that both models are synchronized, i.e. expose equivalent behavior we formalize the models' descriptions. The model description is formalized using the notion of Labeled Transition System (LTS).

A Labeled Transition System is represented as quadruple of a set of states, a set of actions, a set of transitions, and a set of initial states.

By $T_{AMF} = (S_{AMF}, Act_{AMF}, \rightarrow_{AMF}, s^0_{AMF})$ it is denoted an LTS, representing the warning message broadcast state model supported by AMF, where:

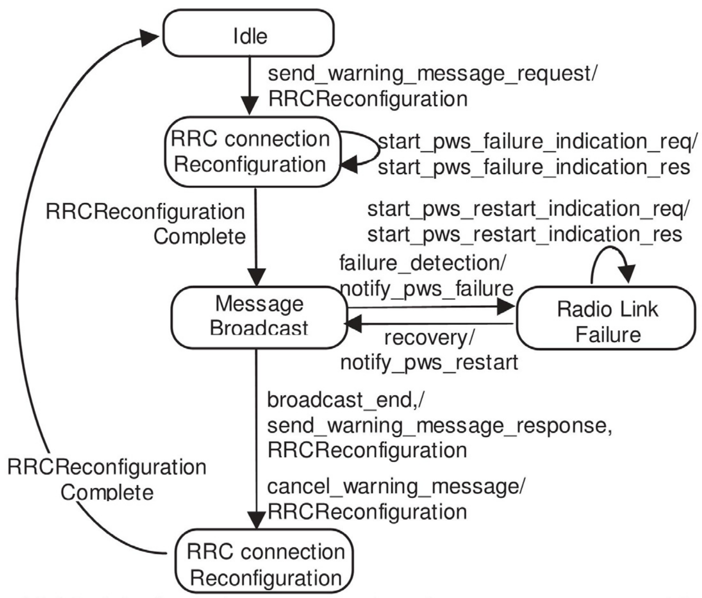

Figure 10. Model of warning message broadcast status, supported by NG-RAN node

S_{AMF} = {Broadcasted [s^A_1], Broadcasting [s^A_2], PWSFailure [s^A_3]};

- Act_{App} = {send_message[t^A_1], start_pws_failure_indication_ res[t^A_2], notify_pws_failure [t^A_3], notify_pws_restart[t^A_4], cancelMessage [t^A_5], send_warning_message_ response [t^A_6], start_pws_restart_indication_res[t^A_7]};

- $\rightarrow_{AMF}$ = {(s_1^A t^A_1 s^A_1), (s^A_2 t^A_2 s^A_2), (s^A_2 t^A_3 s^A_3), (s^A_3 t^A_4 s^A_2), (s^A_2 t^A_5 s^A_1), (s^A_2 t^A_6 s^A_1), (s^A_3 t^A_7 s^A_3)};

- s_0^{AMF} = {s^A_1}.

Short notations for states and actions are given in brackets.

By T_{RAN} = (S_{RAN}, Act_{RAN}, $\rightarrow_{RAN}$, s_0^{RAN}) it is denoted an LTS, representing the warning message broadcast state model supported by NG-RAN node, where:

- S_{RAN} = {Idle [s^R_1], RRCConnectionReconfiguration [s^R_2],
MessageBroadcast [s^R_3], RadioLinkFailure [s^R_4]};

- Act_{RAN} = {send_warning_message_request [t^R_1], start_pws_failure_indication_req[t^R_2], RRCReconfigurationComplete [t^R_3], failure_detection [t^R_4], recovery [t^R_6], start_pws_failure_indication_req [t^R_5], broadcast_end [t^R_7], cancel_warning_message [t^R_8]};

- $\rightarrow_{\mathrm{RAN}}$ = {(s^R_1 t^R_1 s^R_2), (s^R_2 t^R_2 s^R_2), (s^R_2 t^R_3 s^R_3), (s^R_3 t^R_4 s^R_4), (s^R_4 t^R_5 s^R_5), (s^R_4 t^R_6 s^R_3), (s^R_3 t^R_7 s^R_2), (s^R_3 t^R_8 s^R_2), (s^R_2 t^R_3 s^R_1)};

- s_0^{RAN} = {s^R_1}.

Intuitively, in terms of observed behavior, two LTSs are equivalent if one LTS displays a final result and the other LTS displays the same result. The idea of equivalence is formalized by the concept of bisimilarity [9]. In practice, strong bisimilarity puts strong conditions for equivalence which are not always necessary. The weak bisimilarity admits internal transitions to be ignored.

Proposition: T_{AMF} and T_{RAN} are weakly bisimilar.

Proof: As to definition of weak bisimulation, it is necessary to identify a relation between the states of both LTSs, such as for any transition from a state in one LTS there are respective transitions from states in the other LTSs.

By U_{AMFRAN} it is denoted a relation between the states of both LTS, where $U_{AMFRAN} = \{(s_1^A, s_1^R), (s_2^A, s_3^R), (s_3^A, s_4^R)\}$.

Then, the following relationship between the $\rightarrow AMF$ and $\rightarrow RAN$ exists:

1. The AMF initiates warning message broadcast and subscribes for PWS failure indications: for $(s_1^A\ t_1^A\ s_1^A), (s_2^A\ t_2^A\ s_2^A) \exists (s_1^R\ t_1^R\ s_2^R), (s_2^R\ t_2^R\ s_2^R), (s_2^R\ t_3^R\ s_3^R)$.

2. During message broadcasting a failure occurs and the AMF is notified. The AMF subscribes for PWS restart indications: for $(s_2^A\ t_3^A\ s_3^A), (s_3^A\ t_7^A\ s_3^A) \exists (s_3^R\ t_4^R\ s_4^R), (s_4^R\ t_5^R\ s_4^R)$.

3. The problem is fixed and the AMF is notified that the PWS broadcast can restart: for $(s_3^A\ t_4^A\ s_2^A) \exists (s_4^R\ t_6^R\ s_3^R)$.

4. The warning message broadcast completes successfully: for $(s_2^A\ t_6^A\ s_1^A) \exists (s_3^R\ t_7^R\ s_2^R), (s_2^R\ t_3^R\ s_1^R)$.

5. The AMF cancels warning message broadcasting: for $(s_2^A\ t_5^A\ s_1^A) \exists (s_3^R\ t_8^R\ s_2^R), (s_2^R\ t_3^R\ s_1^R)$.

Therefore T_{AMF} and T_{RAN} are weakly bisimilar, i.e. they expose equivalent behavior.

5. Conclusion

In this paper we propose an approach to design RAN application level functions as services. The research is based on functionality of the NGAP between the core network and NG-RAN. We focus on warning message transfer procedures and define a new service. The procedures are described as service interactions. The resource structure is presented and the respective APIs are defined.

Service implementation is discussed by modeling the warning message broadcast status s seen by the NG-RAN and core network. Service-based design improves modularity, facilitates the exposure of network functions to 3rd party applications, and the transition to cloud architecture.

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References

[1] Do, T., Kim, Y. (2018). Usage-Aware Protection Plan for State Management Functions in Service-Based 5G Core Network, *IEEE Access*, vol. 6, p 36906-36915, 2018.

[2] Ma, L., Wen, X., Wang, L., Lu, Z., Knopp, R. (2018). An SDN/NFV based framework for management and deployment of service based 5G core network, *China Communications*, 15 (10), p 86-98, October 2018.

[3] Zhang, C., Wen, X., Wang, L., Lu, Z., Ma, L. (2018). Performance Evaluation of Candidate Protocol Stack for Service-Based Interfaces in 5G Core Network, 2018 IEEE International Conference on Communications Workshops (ICC Workshops), Kansas City, MO, 2018, p 1-6.

[4] Chang, Z., Zhou, Z., Zhou, S., Chen, T., Ristaniemi, T. (2018). Towards Service-Oriented 5G: Virtualizing the Networks for Everything-as-a-Service, *IEEE Access*, vol. 6, p 1480-1489.

[5] He, J., Song, W. (2015). SOARAN: A Service-oriented Architecture for Radio Access Network Sharing in Evolving Mobile Networks, p 1-16, arXiv:1508.00306v1 [cs.NI], August 2015.

[6] Guan, W., Wen, X., Wang, L., Lu, Z., Shen, Y. (2018). A Service-Oriented Deployment Policy of End-to-End Network Slicing Based on Complex Network Theory, *IEEE Access*, Volume 6, p 19691-19701, 2018.

[7] 3GPP TS 38.413 Technical Specification Group Radio Access Network; NG-RAN; NG Application Protocol (NGAP), v15.2.0, 2019, Release 15.

[8] 3GPP TS 38.331 Technical Specification Group Radio Access Network; NR; *Radio Resource Control (RRC) protocol specification*, Release 15, v15.3.0, 2018.

[9] Chen, X. J., De Nicola, R. (2001). Algebraic characteristics of trace and decorated trace equivalences over tree-like structures, *Theoretical Computer Science,* Volume 254, issue 1-2, 2001, p 337-361.