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AGGREGATE COMMUNICATION BETWEEN CONTROL PLANE AND USER PLANE IN A MOBILE NETWORK ENVIRONMENT

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ABSTRACT

With a 3rd Generation Partnership Project (3GPP) fifth-generation (5G) network architecture comprising smaller cell sizes, the movement of a User Equipment (UE) generates frequent signaling from a control plane (CP) to a user plane (UP) to update a user's location. As traffic increases between a CP and a UP, the number of Packet Forwarding Control Protocol (PFCP) control messages increases, requiring a network's nodes to perform additional socket operations. Importantly, each socket input/output (I/O) operation and system call is a costly action from a resource utilization point of view. To address the type of challenge that was described above, techniques are presented herein that reduce the number of socket I/O operations and system calls to, in turn, reduce central processing unit (CPU) and I/O utilization and increase the reliability of signaling and yield better bandwidth utilization. Use of the presented techniques provides a number of benefits including, for example, reduced CPU and I/O resource utilization (resulting a in saving of resources for a gateway node, reduced latency, improved key performance indicators (KPIs) and user experience, and reduced operator capital expenditure), better network bandwidth utilization, etc.

DETAILED DESCRIPTION

With a 3rd Generation Partnership Project (3GPP) fifth-generation (5G) network architecture comprising smaller cell sizes, the movement of a User Equipment (UE) generates frequent signaling from a control plane (CP) to a user plane (UP) to update a user's location. As traffic increases between a CP and a UP, the number of control messages increases. Many of those Packet Forwarding Control Protocol (PFCP) control messages are smaller in size (e.g., below 200 to 300 bytes). To read and write those messages, a network's nodes need to perform socket operations. Importantly, each socket input/output (I/O) operation and system call is a costly action from a resource utilization point of view.

To address the type of challenge that was described above, techniques are presented herein that reduce the number of socket I/O operations and system calls to, in turn, reduce central processing unit (CPU) and I/O utilization.

Aspects of the presented techniques support a new form of message – an Aggregate PFCP message – comprising an Aggregate PFCP Request [e.g., Type = 98 or next available message type in 3GPP TS 29.244] message and an Aggregate PFCP Response [Type = 99] message. The payload of the new message contains a list of individual PFCP Request messages and/or individual PFCP Response messages.

A sending entity may use the new message type to combine multiple PFCP Request messages and/or multiple PFCP Response messages into a single Aggregate PFCP message. The sending entity may either combine N individual messages together or wait for a configurable period of time before sending out a combined message.

Upon receiving an Aggregate PFCP Request message, a receiving entity processes each of the embedded messages separately as if they were received individually on the network. The receiving entity then responds with an Aggregate PFCP Response message. In such a response message the entity may either combine N messages together or wait for a configurable period of time before sending out a combined message.

If a sending entity does not receive a response for a request message which was sent (i.e., included) in an Aggregate PFCP Request message, it may retransmit the request message in the next Aggregate PFCP Request message. A CP and a UP may exchange capability to support Aggregate PFCP messages through a Node Feature in heartbeat request and response messages.

Figure 1, below, illustrates the format of the new Aggregate PFCP message. Among other things the figure indicates the two above-described types – i.e., an Aggregate PFCP Request message and an Aggregate PFCP Response message.

	Bits							
Octets	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
1	Version			Spare	Spare	FO	MP	S=1
2	Message Type (Aggregate PFCP Request [Type=98]/Aggregate PFCP Response [Type=99]							
3-4	Message Length							
5-12	Session Endpoint Identifier							
13-15	Sequence Number							
16	Message Priority				Spare			
	Message 1 Flags							
PFCP	Message 1 Message Type							
16-m Message 1	Message 1 Length							
Payload	Message 1 Payload							
	Message 2 Flags							
PFCP	Message 2 Message Type							
m-n Message 2	Message 2 Length							
Payload	Message 2 Payload							

Figure 1: Aggregate PFCP Request and Response Message Format

The next section of the instant narrative discusses Node Feature negotiation between a CP and a UP in connection with negotiating a message aggregation feature as supported by aspects of the techniques presented herein.

Section 7.4.4 (PFCP Association messages) of the 3GPP technical specification (TS) 29.244 defines the PFCP Association procedures. According to aspects of the techniques presented herein, a PFCP message aggregation feature may be used by both the CP function and the UP function, each of which may indicate support of the corresponding feature during the PFCP Association Setup or Update procedure. If such support is confirmed, then the following requirements are applicable.

The CP Function Features Information Element (IE) that is defined in Section 8.2.58 (CP Function Features) of the 3GPP TS 29.244 identifies the specific features that are supported by the CP function. Similarly, the UP Function Features IE that is defined in Section 8.2.25 (UP Function Features) of the 3GPP TS 29.244 indicates the features that are supported by the UP function. These IEs may be extended to indicate whether a PFCP messages aggregation feature is supported by (respectively) a CP function or a UP function.

A number of the defined PFCP Association messages may be used to indicate PFCP message aggregation during a PFCP Association procedure. Those messages include a PFCP Association Setup Request (see Section 7.4.4.1 of the 3GPP TS 29.244), a PFCP Association Setup Response (see 7.4.4.2 of the same TS), a PFCP Association Update Request (see 7.4.4.3 of the same TS), and a PFCP Association Update Response (see 7.4.4.4 of the same TS).

Section 8.2.58 (CP Function Features) of the 3GPP TS 29.244 defines the CP function features. The CP Function Features IE indicates the specific features that are supported by the CP function, as depicted in Table 8.2.58-1 of the TS. A portion of that TS table is reproduced below as Table 1.

Feature Octet/Bit	Feature	Interface	M/O	Description
5/1	LOAD	Sxa, Sxb, Sxc, N4	O	Load Control is supported by the CP function.
5/2	OVRL	Sxa, Sxb, Sxc, N4	O	Overload Control is supported by the CP function
5/3	EPFAR	Sxa, Sxb, Sxc, N4	O	The CP function supports the Enhanced PFCP Association Release feature (see clause 5.18).
.				
.				
5/8	UIAUR	Sxb, N4	O	CP function supports the UE IP Address Usage Reporting feature, i.e., receiving and handling of UE IP Address Usage Information IE (see clause 5.21.3.2).
6/1	PSUCC	Sxb, Sxc, N4	O	CP function supports PFCP session establishment or modification with Partial Success, i.e., with UP function reporting rules that cannot be activated. See clause 5.2.9.
6/2 (or next available flag CP Functions feature in 3GPP TS 29.244)	Message-level aggregation	Sxa, Sxb, Sxc, N4	O	CP function supports PFCP message-level aggregation.

Table 1: CP Function Features

The CP Function Features IE takes the form of a bitmask where each bit that is set indicates that the corresponding feature is supported. A new bit may be introduced (as indicated in the final row of Table 1, above) to indicate whether or not PFCP message-level aggregation is supported on a Sxa, Sxb, Sxc, and N4 interface.

Section 8.2.25 (UP Function Features) of the 3GPP TS 29.244 defines the UP function features. The UP Function Features IE indicates the specific features that are supported by the UP function, as depicted in Table 8.2.25-1 of the TS. A portion of that TS table is reproduced below as Table 2.

Feature Octet/Bit	**Feature**	**Interface**	**M/O**	**Description**
5/1	BUCP	Sxa, N4	O	Downlink Data Buffering in CP function is supported by the UP function.
5/2	DDND	Sxa, N4	O	The buffering parameter 'Downlink Data Notification Delay' is supported by the UP function.
5/3	DLBD	Sxa, N4	O	The buffering parameter 'DL Buffering Duration' is supported by the UP function.
.				
.				
11/2	MBSN4	N4	O	UPF supports sending MBS multicast session data to associated PDU sessions using 5GC individual delivery.
11/3	PSUPRM	N4	O	UP function supports Per Slice UP Resource Management (see clause 5.35).
11/4 (or next available flag UP Functions feature in 3GPP TS 29.244)	Message-level aggregation	Sxa, Sxb, Sxc, N4	O	UP function supports PFCP message-level aggregation.

Table 2: UP Function Features

The UP Function Features IE takes the form of a bitmask where each bit that is set indicates that the corresponding feature is supported. A new bit may be introduced (as indicated in the final row of Table 2, above) to indicate whether or not PFCP message-level aggregation is supported on a Sxa, Sxb, Sxc, and N4 interface.

Figure 2, below, depicts elements of a Node Feature negotiation process between a CP and a UP during establishment of PFCP message-level aggregation according to aspects of the techniques presented herein.

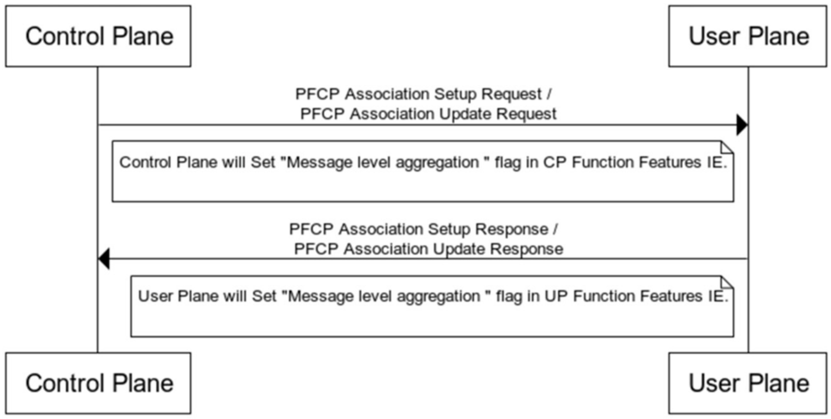

Figure 2: CP and UP Node Feature Negotiation for PFCP Message Aggregation

Figure 3, below, depicts elements of a Node Feature negotiation process between a UP and a CP during establishment of PFCP message-level aggregation according to aspects of the techniques presented herein.

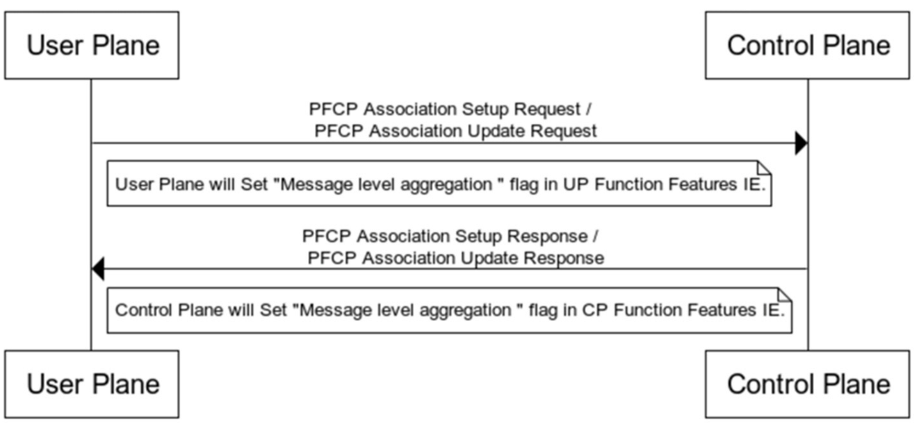

Figure 3: UP and CP Node Feature Negotiation for PFCP Message Aggregation

As illustrated in Figures 2 and 3, above, a PFCP message aggregation process encompasses CP and UP functions negotiating a Node Feature indicating that the CP Function and the UP Function support a PFCP message-level aggregation feature. Elements of that process will be described below.

If a PFCP message-level aggregation feature is supported, a CP function and a UP function define a number of messages (N) that are to be aggregated into an Aggregate PFCP Request [Type = 98] message and an Aggregate PFCP Response [Type = 99] message. Additionally, the CP function and the UP function also define a timer value that will be used to send an Aggregate PFCP Request message and an Aggregate PFCP Response message.

While sending out message over a Sxa, Sxb, Sxc and N4 interface, the CP and UP functions start a timer (if such a timer has not already been started). If N number of messages are not yet aggregated in an Aggregate PFCP Request or an Aggregate PFCP Response message, then the current message may be appended to an existing aggregate message. If N number of messages have been aggregated, or if the above-described timer has expired, then a sending CP or UP sends out the aggregate message.

Upon receiving an Aggregate PFCP Request message or an Aggregate PFCP Response message, a receiving CP or UP processes each of the received embedded messages as a separate message.

If a sending CP or UP does not receive a response to a PFCP message that was sent out in an Aggregate PFCP Request or an Aggregate PFCP Response message, then it may retransmit that message in the next aggregate message. If a receiving CP or UP receives a retransmitted PFCP message, for which it has already sent out a response, then it may retransmit the PFCP response in the next aggregate message. Upon receiving an Aggregate PFCP Request message with sequence number (X) receiving CP or UP may use same sequence number (X) in next an Aggregate PFCP Response message to indicate receipt of an Aggregate PFCP Request message. If a sending CP or UP does not receive an Aggregate PFCP Response with sequence number (X) which was sent in an Aggregate PFCP Request message then sending entity may send an new Aggregate PFCP Request message with with sequence number (X). This new Aggregate PFCP Request message may contain same list of PFCP messages which were sent earlier or it may contain new list of PFCP messages.

In Figures 4 and 5, below, a solution flowchart depicts elements of a PFCP message aggregation procedure according to aspects of the techniques presented herein and reflective of the narrative that was described above. Figure 4, below, presents an exemplary PFCP message aggregation procedure flow for a sending node.

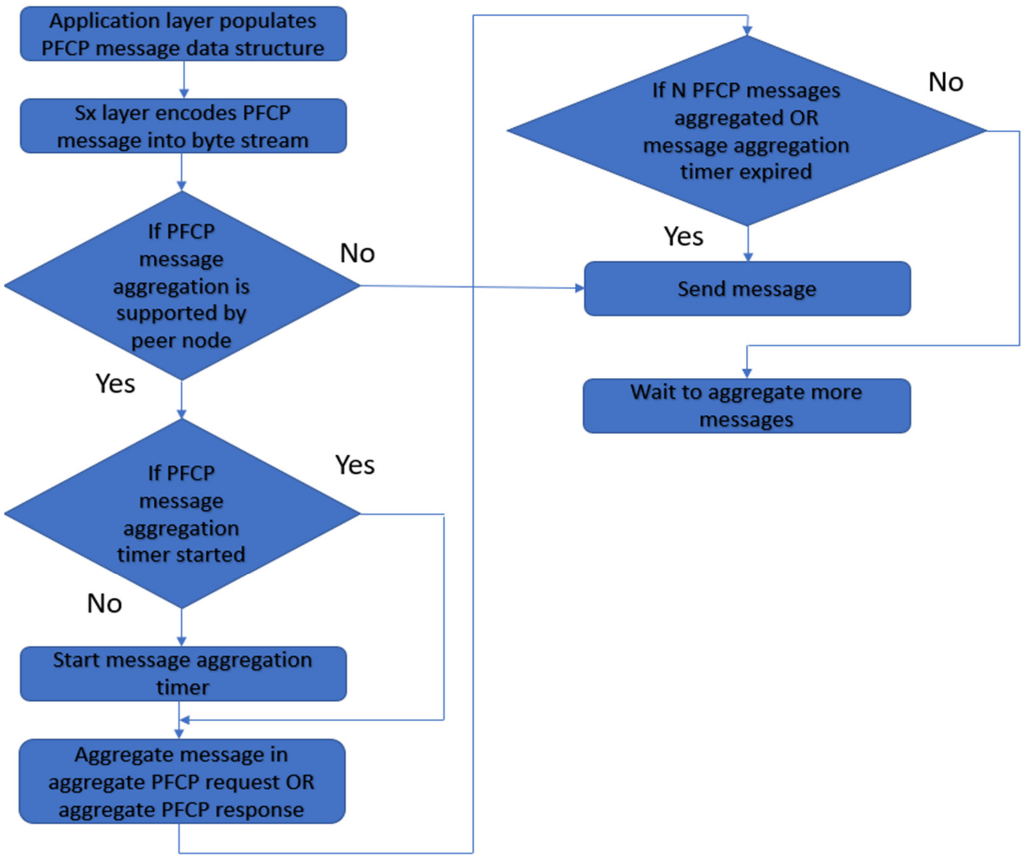

Figure 4: Exemplary PFCP Message Aggregation Procedure – Sending Node

Figure 5, below, presents an exemplary PFCP message aggregation procedure flow for a receiving node.

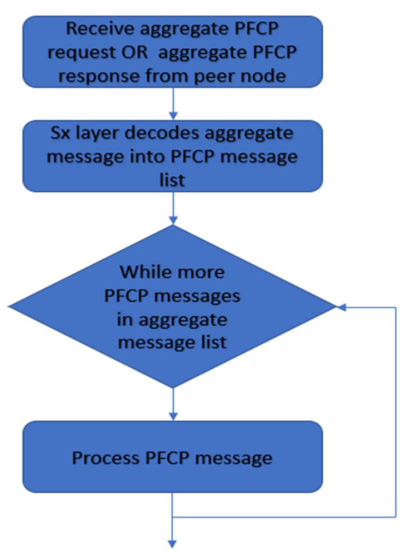

Figure 5: Exemplary PFCP Message Aggregation Procedure – Receiving Node

In summary, techniques have been presented that reduce the number of socket I/O operations and system calls to, in turn, reduce CPU and I/O utilization and increase the reliability of signaling and yield better bandwidth utilization. Use of the presented techniques provides a number of benefits including, for example, reduced CPU and I/O resource utilization (resulting a in saving of resources for a Gateway Node, reduced latency, improved key performance indicators (KPIs) and user experience, and reduced operator capital expenditure), better network bandwidth utilization (as a result of reduced RTP), etc.