5 FLOW OF DOWNLINK DATA

★ Figure 212 illustrates the user plane protocol stack for a standalone Base Station. The figure assumes that the base station uses the Centralised Unit (CU) – Distributed Unit (DU) higher layer split architecture, i.e. the DU hosts the RLC, MAC and Physical layers, while the CU hosts the SDAP and PDCP layers

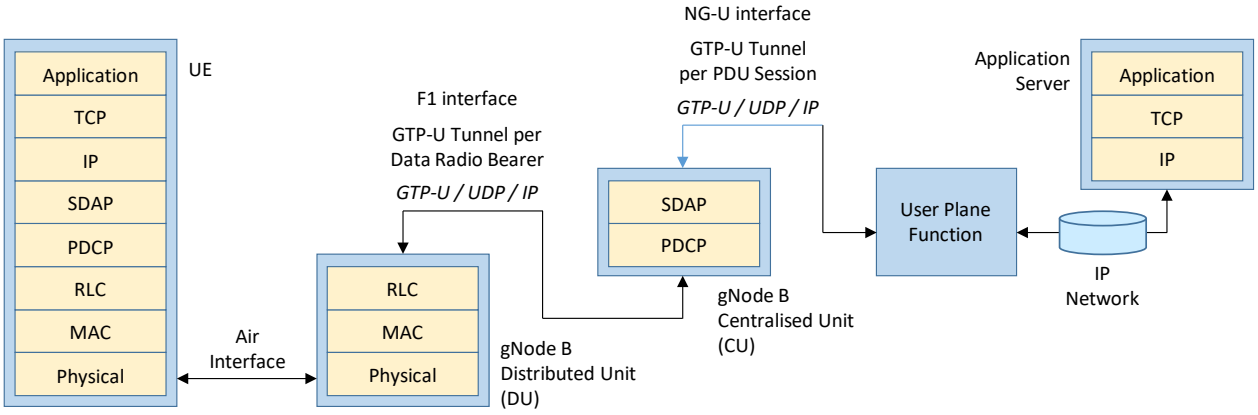

Figure 212 – User Plane protocol stack for Standalone Base Station

★ Consider the example of an end-user browsing the internet and downloading a web page. Internet browsers use the HyperText Transfer Protocol (HTTP) at the Application layer. Assume that the end-user has just sent an HTTP GET command to the server hosting the web page to be downloaded. The application server will proceed to start downloading the web page towards the end-user using Transmission Control Protocol (TCP) / Internet Protocol (IP) packets

★ Figure 213 illustrates the header added by the TCP layer. The standard header size is 20 bytes although it can be larger when optional header fields are included. The TCP header specifies both the Source and Destination Ports to identify the higher layer application. By default, HTTP uses port number 80. The header also includes a Sequence Number to allow re-ordering and packet loss detection at the receiver. The Acknowledgement Number provides a mechanism to acknowledge packets, while the Data Offset defines the size of the header. The Window Size specifies the number of bytes which the sender is willing to receive. The Checksum allows bit error detection across both the header and payload. The Urgent Pointer can be used to indicate that some data needs to be handled with a high priority

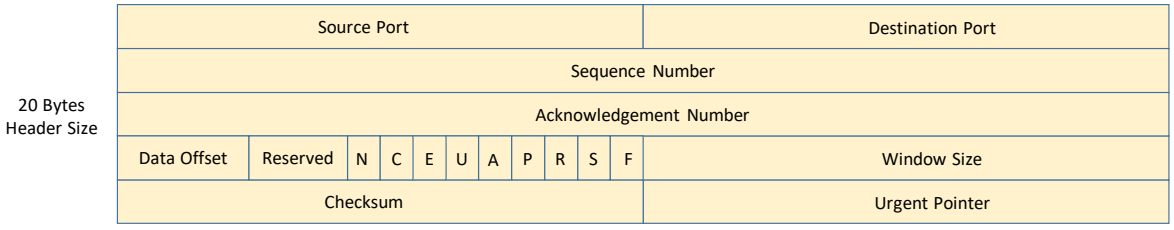

Figure 213 – TCP Header (20 bytes)

★ Figure 214 illustrates the header added by the IP layer (assuming IPv4). The standard header size is 20 bytes although it can be larger when optional header fields are included. The IP header specifies both the Source and Destination IP Addresses. Routers use the Destination IP address to forward packets in an appropriate direction. The Version header field has a value of 4 when using IPv4. The Header (HDR) Length field specifies the size of the header, while the Total Length field specifies the size of the packet. The Differentiated Services Code Point (DSCP) can be used to prioritise the packet, whereas the Explicit Congestion Notification (ECN) can be used to indicate network congestion. The Protocol field specifies the type of content within the payload of the packet. TCP is identified using a protocol number of 6

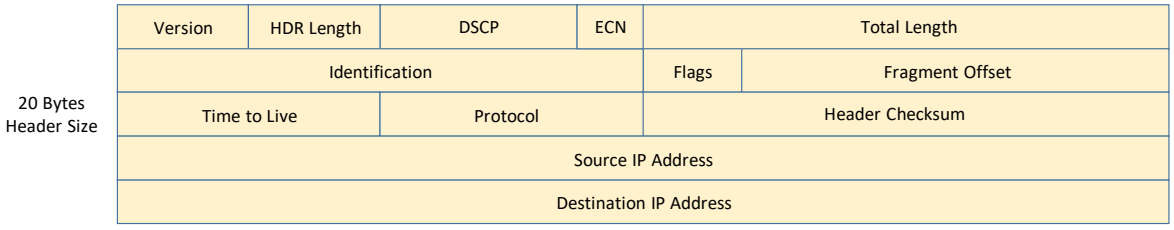

Figure 214 – IP Header (20 bytes)

- ★ Once the IP header has been added, the packet is routed across the IP network towards the User Plane Function (UPF) which provides the point of entry into the 5G Core Network. The IP network relies upon its lower layers to transport packets between routers. For example, Ethernet could be used as a layer 2 protocol to transfer IP packets between routers
- ★ The UPF is responsible for mapping the TCP/IP packet onto a specific QoS Flow belonging to a specific PDU Session. The UPF uses packet inspection to extract various header fields. These header fields are compared against the set of Service Data Flow (SDF) Templates to identify the appropriate PDU Session and QoS Flow. For example, packets can be mapped onto a specific PDU Session and QoS Flow using a unique combination of {source IP address 'X'; destination IP address 'Y'; source port number 'J'; destination port number 'K'}. The UPF receives the set of SDF Templates from the Session Management Function (SMF) during the setup of the PDU Session
- ★ After identifying the appropriate PDU Session and QoS Flow, the UPF uses a GTP-U tunnel to forward the data towards the gNode B (the 5G Core Network architecture may chain multiple UPFs so the first UPF may have to use a GTP-U tunnel to forward the data towards another UPF before it is forwarded towards the gNode B). A GTP-U tunnel is setup for each PDU Session. This means that the Tunnel Endpoint Identifier (TEID) within the GTP-U header identifies the PDU Session but does not identify the QoS Flow. A 'PDU Session Container' is added to the GTP-U header to provide information which identifies the QoS Flow. Figure 215 illustrates the structure of a GTP-U header which includes the 'PDU Session Container'. The structure of the GTP-U header is specified within 3GPP TS 29.281, whereas the content of the 'PDU Session Container' is specified within 3GPP TS 38.415

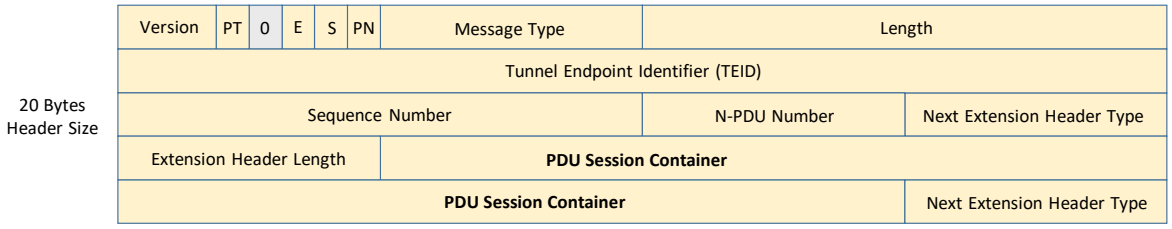

Figure 215 – GTP-U Header with PDU Session Container

- ★ The content of the 'PDU Session Container' is presented in Figure 216. The 'PDU Type' value of '0' indicates that the PDU is a downlink packet rather than an uplink packet. The Paging Policy Presence (PPP) field indicates whether or not a Paging Policy Indicator (PPI) is included within the header. The UPF can provide a PPI to the gNode B to influence the priority of the paging procedure which may be triggered by the arrival of the downlink packet, i.e. when the UE is RRC Inactive. The Reflective QoS Indicator (RQI) specifies whether or not Reflective QoS should be applied for this QoS Flow

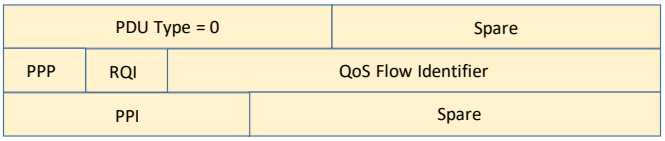

Figure 216 – PDU Session Container included within GTP-U header

- ★ A GTP-U tunnel uses a UDP/IP protocol stack so UDP and IP headers are added before forwarding the packet across the transport network. UDP provides simple connectionless data transfer. Figure 217 illustrates the structure of a UDP header. The Source and Destination Ports identify the higher layer application. In this case, the higher layer application is GTP-U which has a registered port number of 2152

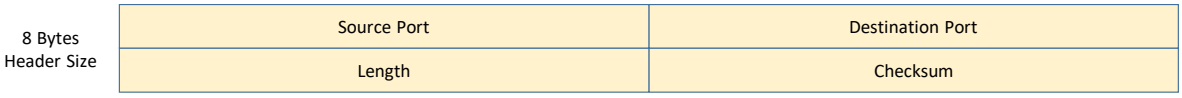

Figure 217 – UDP Header (8 bytes)

- ★ The addition of an IP header for routing across the GTP-U tunnel means that the data packet now has two IP headers. These are commonly referred to as inner and outer IP headers. Both headers are illustrated in Figure 218. The UPF can prioritise packets using the DSCP field within the outer IP header. The headers associated with the GTP-U tunnel are removed at the far end of the tunnel, i.e. at the gNode B, or at another UPF if the Core Network architecture uses chained UPFs

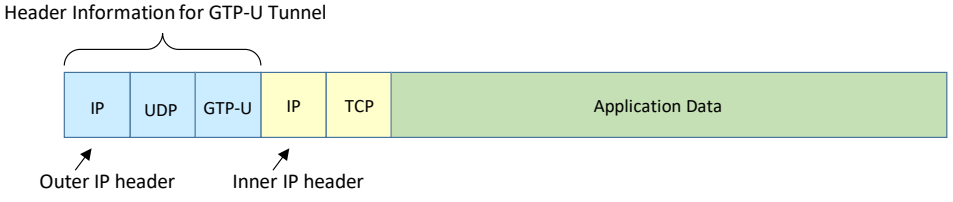

Figure 218 – Headers for data transfer across GTP-U tunnel

- The gNode B Centralised Unit (CU) uses the GTP-U header information to identify the PDU Session and QoS Flow associated with the data packet. The packet is then processed by the Service Data Adaptation Protocol (SDAP) layer which is responsible for mapping the packet onto a specific Data Radio Bearer (DRB). This mapping is illustrated in Figure 219. The SDAP layer can be configured to transfer data without the addition of an SDAP header. Alternatively, the SDAP layer can add a header to allow the use of Reflective QoS. In this case, the SDAP header specifies the QoS Flow associated with the packet. The UE can use this information to deduce the mapping between QoS Flow and DRB for its uplink transmissions. The SDAP layer is specified in 3GPP TS 37.324 and is described in greater detail in section 5.1. The SDAP layer passes the packet to the PDCP layer using its allocated DRB
- The PDCP layer provides security in terms integrity protection and ciphering. Integrity protection is provided by calculating an authentication code which is appended to the packet as header information (MAC-I field). This authentication code is used by the receiver to verify that the packet is genuine, and has not been inserted by an intruder. Ciphering is applied to the payload of each PDCP packet after the authentication code has been calculated. Ciphering scrambles the sequence of bits to make the packet unreadable unless the receiver knows the ciphering key to reverse the scrambling. The PDCP layer also adds header information which includes the PDCP sequence number. This sequence number is used for re-ordering at the receiver. In some cases, the PDCP layer can provide header compression. This depends upon the end-user application and is typically applied to speech packets rather than data packets

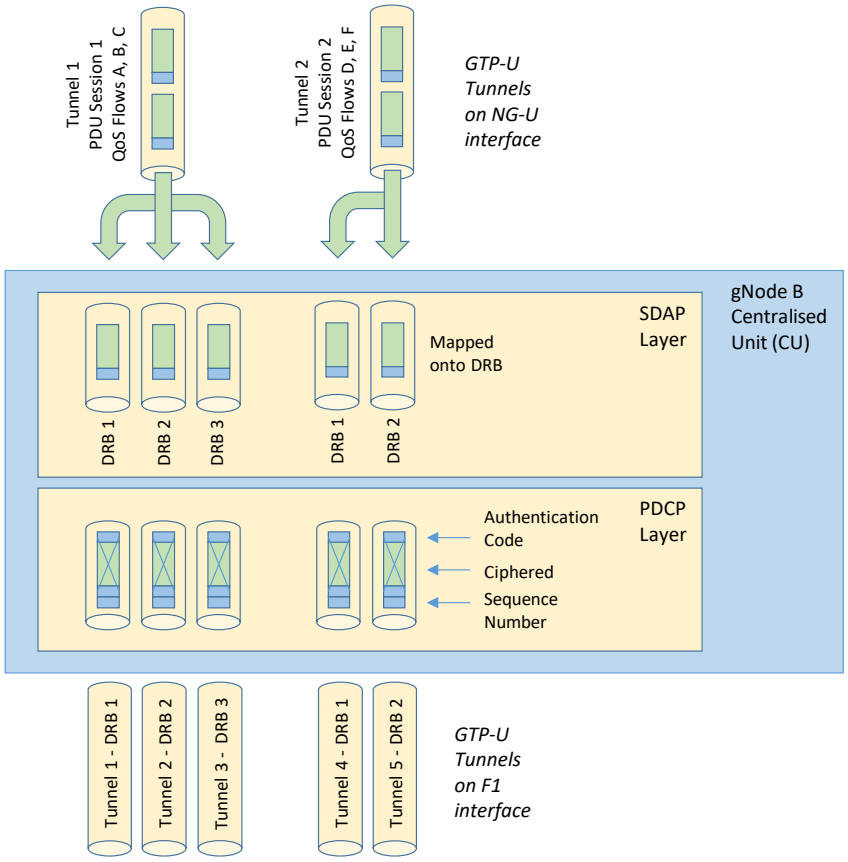

Figure 219 – SDAP and PDCP processing within the gNode B Centralised Unit (CU)

- The gNode B Centralised Unit forwards the PDCP PDU to the appropriate gNode B Distributed Unit. This involves transferring the packets across the F1 interface using GTP-U tunnels. At this stage, packets are mapped onto their Data Radio Bearer (DRB) so GTP-U tunnels are setup 'per DRB' rather than 'per PDU Session' The GTP-U header is modified to accommodate the 'NR RAN Container', rather than the 'PDU Session Container' used for the NG-U interface. The GTP-U header used for the F1 interface is illustrated in Figure 220. The 'NR RAN Container' accommodates the header information generated by the New Radio User Plane Protocol specified in 3GPP TS 38.425

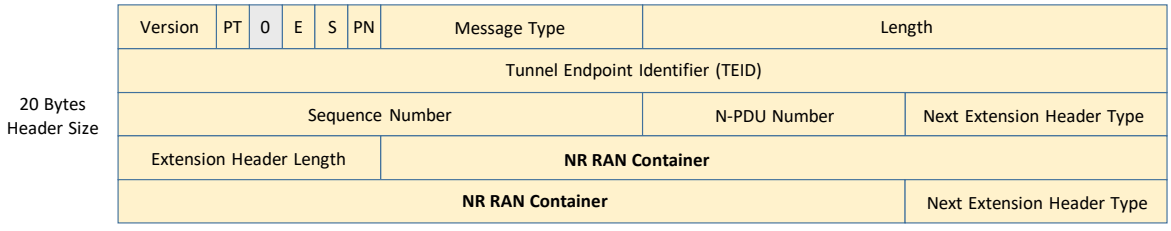

Figure 220 – GTP-U Header with NR RAN Container