5G Sidelink Positioning in 3GPP Release 18 and Release 19

Trung-Kien Le, Sebastian Wagner, Florian Kaltenberger
EURECOM, Sophia-Antipolis, France
Trung-Kien.Le@eurecom.fr

***Abstract*—New Radio (NR) sidelink (SL) positioning has been introduced in the Third Generation Partnership Project (3GPP) Release 18 to enhance NR SL communication that has been developed since 3GPP Release 16. SL positioning is used to determine the user equipment's (UE) position to support use cases such as Vehicle-to-Everything (V2X) communications, public safety, commercial use-case and Industrial Internet of Things (IIoT). The design of SL positioning requires integration into the existing framework of the NR SL communication. A novel sequence to generate SL-positioning reference signal (SL-PRS) needed to be defined. Besides that, resource pools, resource allocation, time and frequency domain patterns also required standardization to avoid collisions between the SL-PRS transmissions and the legacy NR SL transmissions. There is strong support to extend SL positioning to unlicensed spectrum (SL-U) in Release 19. This article provides a detailed overview of the physical layer design of Rel-18 NR SL positioning and addresses some of the challenges for SL-U positioning in Release 19.**

***Index Terms*—5G, sidelink positioning, 3GPP Release 18, 3GPP Release 19**

I. Introduction

In response to the growing demand for Vehicle-to-Everything (V2X) communications, the Third Generation Partnership Project (3GPP) introduced direct Device-to-Device (D2D) communications within Release 12. This marked the inauguration of the PC5 interface, which operates as a sidelink (SL) interface, facilitating direct communication between devices. Building upon the foundations laid in Release 12, the standardization of Long-Term Evolution V2X communications commenced in Release 14 and was further enriched in Release 15. Release 15 also marked the inception of the 5G New Radio (NR) standard. Subsequently, in Release 16, the V2X standard based on the 5G air interface was developed. The advent of Release 18 saw the introduction of SL positioning techniques, designed to enhance NR SL by providing devices engaged in SL communication with the ability to determine their absolute or relative positions. This innovation finds applicability in various use cases, including V2X, public safety, commercial applications, and the Industrial Internet of Things (IIOT) [14].

User equipment (UE) leverages positioning information from other UEs to either complement or replace positioning information from the base station (gNB). Such functionality proves invaluable when UEs operate in conditions of limited coverage or encounter challenging scenarios like non-line-of-sight (NLOS) transmission between the UE and the gNB. Notably, SL positioning also alleviate Uu signaling burden by reducing the need for Uu (the interface between the UE and the gNB) positioning when a UE's position can be determined via Uu positioning, while the positions of other UEs can be ascertained through SL positioning, based on the UE's location obtained through Uu positioning. Prior to Release 18, standards governing NR positioning over the Uu interface and NR SL communication were already in place. The introduction of SL positioning necessitated the development of new solutions aimed at seamlessly integrating SL positioning into the existing NR SL framework, guided by the principles established for NR positioning over the Uu interface.

In Release 18, the standardization of sidelink communication was extended to unlicensed spectrum, while SL positioning was exclusively standardized within licensed spectrum. Consequently, in upcoming releases such as Release 19 and beyond, there is a compelling need to standardize SL positioning within unlicensed spectrum. This harmonization is essential to ensure compatibility with sidelink communication and to effectively support applications that demand high data rates.

This study focuses on SL positioning in Release 18 and anticipates the developments in Release 19. In Section II, we delve into the requisites and usage scenarios associated with SL positioning within Release 18. Section III outlines the characteristics standardized in Release 18 pertaining to SL positioning. In Section IV, we shift our focus towards the future trajectory of SL positioning, particularly within the unlicensed spectrum domain anticipated in Release 19. Here, we introduce proposed features encompassing the mini-slot structure and the control signal for back-indication. Section V presents the numerical outcomes derived from the proposed strategies. Finally, Section VI concludes this work.

II. SL Positioning Scenarios and Requirements in Release 18

In the context of SL positioning, two operational scenarios have been examined. The first scenario involves SL positioning relying solely on measurements obtained via PC5 accommodating situations such as when a User Equipment (UE) finds itself outside the coverage area of the gNB, necessitating its reliance on measurements from the SL-PRS and measurement reports transmitted by other devices. In the second scenario, a combination of measurements from both PC5 and Uu interfaces is employed to enable the utilization of hybrid positioning methods, particularly when the UE operates within the gNB coverage area.

Release 18 has conducted a comprehensive investigation into four distinct use cases for SL positioning, namely V2X, public safety, commercial applications, and Industrial Internet of Things (IIoT). In the context of V2X and public safety use cases, both in-coverage and out-of-coverage scenarios have been thoroughly explored. Conversely, for IIoT and commercial use cases, the focus primarily centers on in-coverage scenarios. The specific requirements of SL positioning within these four use cases are detailed in Table I. The performance evaluation of SL positioning has been conducted within the Frequency Range 1 (FR1), spanning from 410 MHz to 7.125 GHz, encompassing channel bandwidths of up to 100 MHz. Additionally, the optional utilization of Frequency Range 2 (FR2), spanning from 24.25 GHz to 52.6 GHz, with channel bandwidths of up to 400 MHz, has been considered for assessing the performance of SL positioning.

III. SL POSITIONING FEATURES IN RELEASE 18

A. Positioning methods

In SL positioning, a target User Equipment (UE) is defined as a UE for which the position is to be determined with the assistance of an anchor UE. The anchor UE serves the purpose of transmitting or receiving SL-PRS signals via the PC5 interface and provides relevant positional information concerning the target UE. As illustrated in Fig.1, the target UE, e.g. a vehicle, can transmit or receive SL-PRS signals from Road Side Units (RSUs) acting as anchor UEs. Leveraging the known positions of these RSUs, the target UE can precisely determine its absolute position. Moreover, the target UE has the capability to transmit or receive SL-PRS from other vehicles enabling the target UE to compute the distance or direction between two UEs to determine its relative position.

Several methods, including SL-Round-Trip-Time (SL-RTT), SL-Angle-of-Arrival (SL-AoA), SL-Time-Difference-of-Arrival (SL-TDOA), and SL-Angle-of-Departure (SL-AoD), are employed by UEs to determine either their absolute or relative positions with a high degree of accuracy.

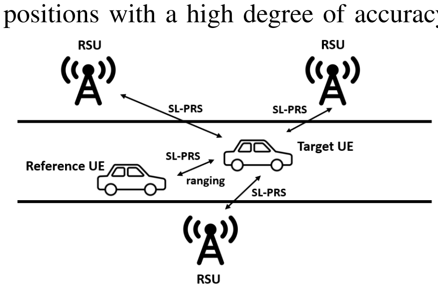
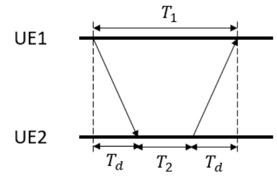
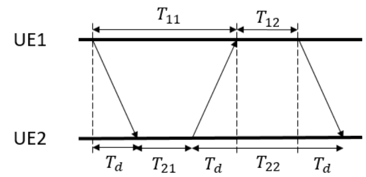


Fig. 1. Absolute positioning and relative positioning.

In the SL-RTT method, two UEs transmit and receive SL-PRS signals to estimate the distance separating them. Fig.2(a) illustrates the Single-sided RTT approach, in which each UE transmits only once. However, clock drift within each UE can introduce errors into the positioning measurement. To counteract the impact of clock drift, the Double-sided RTT method is employed, as depicted in Fig.2(b) where one UE transmits twice while the other UE transmits once. Importantly, the sequence of SL-PRS transmissions between the UEs is not restricted to adhere to the order depicted in Fig. 2(b). Consequently, both the Single-sided and Double-sided RTT methods are incorporated into SL positioning techniques, and utilized for both absolute and relative positioning.



(a) SL Single-sided RTT.



(b) SL Double-sided RTT.

Fig. 2. SL-RTT.

SL-AoA and SL-AoD rely on angle measurements and remain unaffected by time synchronization errors. SL-AoA encompasses measurements for both SL Azimuth of Arrival and SL Zenith of Arrival, with the UEs equipped with multiple antenna elements to facilitate angle measurement. The accuracy of angle of arrival measurement depends upon factors such as the number of antennas at the device, their spatial arrangement, and the relative distances between these antennas. SL-AoA is utilized for both absolute and relative positioning. In contrast, SL-AoD relies on measurements from SL-PRS at the transmitting UE. However, in many SL positioning scenarios, a UE may possess either a single transmitting antenna/chain or two transmitting antennas/chains. Consequently, SL-AoD may not always prove to be the most efficient option and is deprioritized in favor of the other three methods.

Moving to SL-TDOA, it requires a UE to measure the time of arrival from multiple nodes and subsequently calculate the time differences based on these measurements. SL-TDOA necessitates the participation of at least three UEs: one UE receives and measures the time of arrival of SL-PRS, while the remaining two UEs transmit SL-PRS signals. Although achieving synchronization among the UEs can be challenging, SL-TDOA remains a viable option as it doesn't demand two-way signal transmissions between transmitter and receiver. This method primarily serves absolute positioning, particularly in scenarios where the locations of anchor UEs are known, simplifying the synchronization process.

B. Measurements and Reporting

The following measurements are defined based on SL-PRS obtained via the methods in Section III-A: Rx-Tx measurement based on SL-PRS, Reference Signal Time Difference (RSTD), Reference Signal Received Power (RSRP), Reference Signal Received Path Power (RSRPP), Relative Time of Arrival (RTOA), Azimuth of Arrival (AoA), Zenith of arrival (ZoA).

SL-PRS based Rx-Tx measurement is used in the SL-RTT positioning method. SL-PRS-RSTD and SL-PRS-RTOA measurements are used in the SL-TDoA positioning method. SL-PRS-AoA and ZoA measurements are used in the SL-AoA positioning method.

TABLE I
REQUIREMENTS FOR SL POSITIONING

Requirements	V2X	Public safety	IIOT	Commercial
Horizontal accuracy	Set A: 1.5 m (absolute or relative) for 90% of UEs Set B: 0.5 m (absolute or relative) for 90% of UEs	1 m (absolute or relative) for 90% of UEs	Set A: 1 m (absolute or relative) for 90% of UEs Set B: 0.2 m (absolute or relative) for 90% of UEs	1 m (absolute or relative) for 90% of UEs
Vertical accuracy	Set A: 3 m (absolute or relative) for 90% of UEs Set B: 2 m (absolute or relative) for 90% of UEs	2 m (absolute or relative between 2 UEs) for 90% of UEs 0.3 m (relative positioning change for one UE) for 90% of UEs	Set A: 1 m (absolute or relative) for 90% of UEs Set B: 0.2 m (absolute or relative) for 90% of UEs	2 m (absolute or relative) for 90% of UEs
Relative speed		up to 30 km/h	up to 30 km/h	up to 30 km/h

SL-PRS-RSRP and SL-PRS-RSRPP measurements are used in the SL-AoD positioning method. SL-PRS-RSRP is defined as the linear average over the power contributions (in W) of the resource elements that carry SL PRS configured for RSRP measurements within the considered measurement frequency bandwidth. SL-PRS-RSRPP is defined as the power of the linear average of the channel response at the i^{th} path delay of the resource elements that carry SL PRS configured for the measurement, where SL PRS-RSRPP for the first path delay is the power contribution corresponding to the first detected path in time.

After measuring SL-PRS, the UE sends a measurement report to the Location Management Function (LMF) or other UEs. Location information and quality information of the location of a UE, time stamps associated with a SL positioning measurement, SL-PRS resource identity (ID), LOS/NLOS indicator can be included in the measurement report. Based on the measurement report, the target UE does the calculation by itself to determine its position or the LMF does the calculation and transmits position information to the target UE.

C. SL Positioning Reference Signal Sequence

The SL-PRS sequence is generated based on the Gold sequence as downlink (DL)-PRS defined by

$$r(n) = \frac{1}{\sqrt{2}}(1 - 2c(2n)) + j\frac{1}{\sqrt{2}}(1 - 2c(2n+1)) \quad (1)$$

where $c(i)$ is a pseudo-random sequence as defined in [1], n is the index of the sequence.

The pseudo-random sequence generator $c(i)$ is initialized based on the initialization equation for DL-PRS as defined in [1]. The $c(i)$ initialization equation is defined as a function of slot number, symbol number and a new parameter $n_{ID,seq}^{SL-PRS}$ ranging from 0 to 4095. $n_{ID,seq}^{SL-PRS}$ is provided by higher layers or based on the 12 least significant bits of the cyclic redundancy check (CRC) of the PSCCH associated with SL-PRS in case it is not provided by higher layers.

The Gold sequence is used for SL-PRS because it is more robust to time and frequency errors for positioning measurements than a Zadoff-Chu sequence. This is important in the V2X scenarios with synchronization error and the high mobility UEs.

D. Resource Pool

SL-PRS is transmitted as unicast, groupcast (not including many to one), broadcast in either a dedicated resource pool for SL-PRS or a shared resource pool with SL communication used to transmit SL data.

1) Dedicated Resource Pool

SL-PRS can be transmitted in a dedicated resource pool configured to be separated from the resource pool for the legacy SL communication used to transmit SL data. The dedicated resource pool allows SL-PRS to be transmitted with a larger bandwidth and avoid the collision with the legacy SL communication. One disadvantage of the dedicated resource is that it requires more resources to be configured for SL-PRS.

Sidelink control information (SCI) carried by Physical Sidelink Control Channel (PSCCH) in 2 or 3 OFDM symbols is transmitted with SL-PRS with the same symbol-level transmission power in the dedicated resource pool to indicate the SL-PRS resource. The first PSCCH symbol is mapped to the second symbol available for SL transmissions in a slot. The subchannel containing PSCCH is associated with the SL-PRS source ID. SCI is also used to reserve SL-PRS resources (the maximum number of reservations is 3) for SL-PRS transmissions of the transmitting UE. SCI is single stage and multiplexed with the associated SL-PRS in time division multiplexing (TDM) in a slot. One example of slot structure in the dedicated resource pool is shown in Fig. 3.

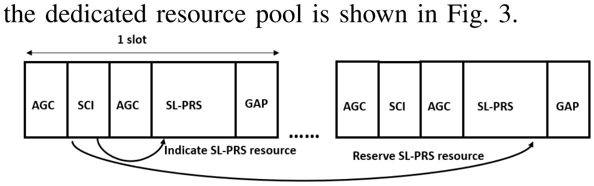


Fig. 3. Slot structure in the SL-PRS dedicated resource pool.

2) Shared resource pool

SL-PRS can be multiplexed with Physical Sidelink Shared Channel (PSSCH) and Physical Sidelink Feedback Channel (PSFCH) from the legacy SL communication in a slot in a shared resource pool. The SL-PRS is mapped after the last symbol with the second stage SCI and the first PSSCH DMRS symbol. The SL-PRS bandwidth and transmit power are the same as for PSSCH. SL-PRS symbols are consecutive in a slot. One example of a slot structure where SL-PRS and PSSCH are multiplexed in a shared resource pool is shown in Fig. 4. SCI is used to indicate both PSSCH and SL-PRS resources. SCI also can be used to reserve SL-PRS resources in the next slots (the maximum number of reservations is 3) for the transmitting UE. SL-PRS is not mapped in the same symbol with PSCCH demodulation reference signal (DMRS) and PSFCH.

E. Resource Allocation

Two schemes (Scheme 1 and Scheme 2) are defined for the SL-PRS resource allocation in the dedicated and shared

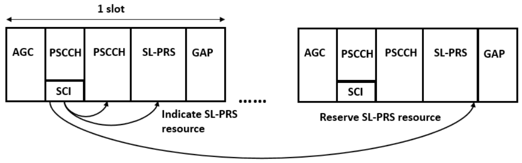


Fig. 4. Slot structure in the shared resource pool.

resource pools.

1) Scheme 1

Scheme 1 is similar to Mode 1 in NR SL communications where SL-PRS resource allocation is a network-centric operation. The gNB allocates SL-PRS resource to the UE via dynamic-grant (DG) or configured-grant (CG) scheduling.

In DG scheduling, the UE sends a scheduling request (SR) to the gNB through Physical Uplink Control Channel when it needs to transmit SL-PRS. Upon receiving SR, the gNB responds with a grant transmitted in Physical Downlink Control Channel to allocate the SL-PRS resource.

In CG scheduling, the gNB configures the CG resources to the UE to transmit SL-PRS without having to transmit SR every time. There are two types of CG scheduling. In Type 1, the CG resources are configured by the gNB through Radio Resource Control (RRC) signalling and the UE uses these CG resources to transmit SL-PRS until the resources are released by the gNB through RRC signalling. In Type 2, the CG resources are configured by the gNB through RRC signalling. After that, the gNB sends downlink control information to activate/deactivate the CG resources.

2) Scheme 2

Scheme 2 used for the UE in the out-of-coverage area is similar to Mode 2 in NR SL communications where SL-PRS resource allocation is a UE autonomous operation. A UE chooses the SL-PRS resources from the resource pool by sensing the resources or random resource selection.

In the sensing-based resource allocation, the UE decodes PSCCH transmitted by other UEs in the sensing window period then excludes the occupied resources from the candidate resource set. The resources for SL-PRS transmission are selected from the candidate resource set in the selection window. The UE measures the signal in the candidate resource set and excludes the resources if the measured RSRP based on PSCCH DMRS is higher than a threshold and the priority of the measured resources is higher than its SL-PRS priority. If its SL-PRS has a higher priority and pre-emption is enabled, it can select those resources and send a preemption indication to other UEs so that other UEs do not transmit in those resources. Priority value for SL PRS is provided by higher layers. After excluding the occupied resources, the UE informs the remaining resources to the Medium Access Control (MAC) layer then resources are selected randomly from the remaining resources by the MAC layer. After selecting the resource, the UE continues to sense the resources in the sensing window to check if the chosen resource is still available. If the chosen resource is excluded, the UE reselects the resource by choosing randomly the resource in the remaining resources again in the selection window.

In some SL positioning scenarios, random resource selection is used because the UE is limited in power consumption or has a strict latency requirement so it cannot carry out the sensing operation to select the resources for SL-PRS transmission. All resources within the selection window in the resource pool are the candidates for resource selection. The UE selects the resources for SL-PRS transmission randomly in the resource pool without knowing the resources being occupied or not.

F. SL-PRS: Time and Frequency Domain Patterns

In the frequency domain, SL-PRS has a comb structure where SL-PRS occupies every N^{th} sub-carrier. The values N of 2 and 4 (shown in Fig. 5) are supported but the values of N larger than 12 are not supported in both dedicated and shared resource pools. The value $N = 6$ is supported in the dedicated resource pool and $N = 1$ is supported in the shared resource pool. Sub-carrier spacing of 15 kHz, 30 kHz and 60 kHz in FR1 and 60 kHz and 120 kHz in FR2 is supported.

In the time domain, SL-PRS occupies M OFDM symbols excluding the symbol used for AGC and gap. The values of M range from 1 to 9 in the dedicated resource pool. The OFDM symbols for SL-PRS in a slot are consecutive.

SL-PRS patterns with full staggering where $M \geq N$ and the resource element offset in each symbol is different are supported in the dedicated and shared resource pools. One example of SL-PRS patterns with full staggering with comb size of 4 and 4 symbols is shown in Fig. 5. SL-PRS patterns with partial staggering where $M < N$ and the resource element offset in each symbol is different are supported in the dedicated and shared resource pools. SL-PRS pattern with partial staggering is shown in Fig. 6 where SL-PRS occupies 2 symbols with comb size of 4.

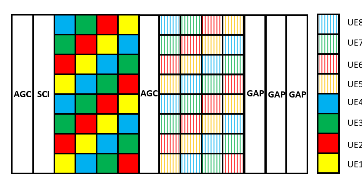


Fig. 5. Comb-based and TDM-based multiplexing with full staggering pattern.

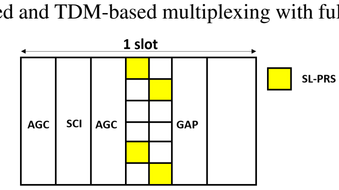


Fig. 6. Partial staggering with comb size of 4 and 2 symbols.

Comb-based multiplexing is supported in the dedicated resource pool allowing multiple UEs having same values of M and N to be multiplexed in frequency as shown in Fig. 5.

TDM-based multiplexing of SL-PRS from different UEs in a slot is supported in the dedicated resource pool where multiple UEs can be multiplexed in TDM in a slot as shown in Fig. 5. The UE1, UE2, UE3 and UE4 occupying 4 SL-PRS symbols are multiplexed in time domain in one slot with the UE5, UE6, UE7 and UE8 occupying 4 SL-PRS symbols. Only the UEs with the same pair (M, N) are multiplexed in one TDM group. There are maximum 4 TDM groups for SL-PRS multiplexing in a slot and there is no gap between two TDM SL-PRS resources.

SL power control for SL-PRS is an open-loop scheme as the power control for SL communication (PSCCH, PSSCH, PSFCH, Sidelink-Synchronization signal block).

IV. Future SL Positioning Features in Release 19

In Release 18, the operation of sidelink communication is extended to unlicensed spectrum to support the commercial use cases such as interactive gaming, Internet of Everything, etc. with an increase of data rate. Sidelink in unlicensed spectrum has been standardized in Release 18 while sidelink positioning has only been standardized in licensed spectrum. Therefore, the operation of sidelink positioning will likely be extended to unlicensed spectrum in the next release to be compatible with sidelink communication.

A. Challenges with Sidelink Positioning in Unlicensed Spectrum

1) SL-PRS Dedicated Resource Pool in Unlicensed Spectrum

SL-PRSs of multiple UEs can be multiplexed in a slot in TDM in the dedicated resource pool as shown in Fig. 7. SL resource that the UE1 uses to transmit SL-PRS1 is multiplexed in a slot in TDM with SL resource that the UE2 uses to transmit SL-PRS2. The locations of the UE1 and UE2's SL resources are indicated by SCI transmitted at the beginning of a slot as the legacy slot structure of sidelink communication.

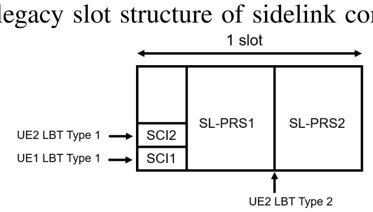


Fig. 7. SL-PRS multiplexing in TDM in the dedicated resource pool.

In unlicensed spectrum, the UE has to do Listen-before-talk (LBT) before a transmission. In Fig. 7, the UE1 and UE2 must do LBT to initiate the COTs before transmitting SCI and SL-PRS. After the UE1 succeeds in acquiring the channel, it starts to transmit SCI1 and SL-PRS1. For the UE2, after a successful LBT, it transmits SCI2 to indicate the location of SL-PRS2. Due to the gap between SCI2 and SL-PRS2 transmission, the UE2 must do another LBT before transmitting SL-PRS2 and SL-PRS2 transmission might be blocked by SL-PRS1 transmission or other WIFI devices' transmission. It causes a loss of SL-PRS or a latency in determining the UE's position.

2) SL-PRS shared resource pool in unlicensed spectrum

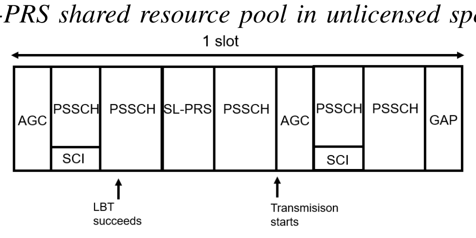


Fig. 8. SL-PRS non-transmission due to LBT uncertainty.

In a shared resource pool, SL-PRS is transmitted with other physical channels. In unlicensed spectrum, a UE must do LBT before transmitting. Because of LBT uncertainty, a UE might acquire the channel after the first starting position with PSCCH occasion in a slot as shown in Fig. 8. It cannot transmit SL-PRS in that slot even if LBT succeeds before SL-PRS occasion and must wait until the next SL-PRS resource because SL-PRS resource location cannot be indicated by an associated SCI. It causes latency in determining the position of a UE.

Due to the uncertainty of LBT, the new features to support SL-PRS transmission in the dedicated and shared resource pool in unlicensed spectrum are required.

B. Proposed features for sidelink positioning in unlicensed spectrum

1) A mini-slot structure for SL-PRS in unlicensed spectrum

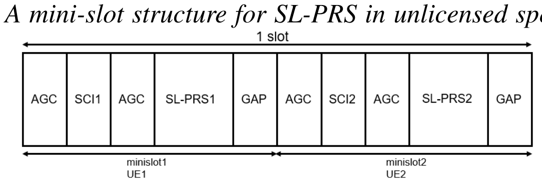


Fig. 9. The mini-slot structure in SL-PRS dedicated resource pool in unlicensed spectrum.

In the proposed slot structure for the SL-PRS dedicated resource pool in unlicensed spectrum, a slot is divided into the mini-slots so that the UE can transmit SCI at the beginning of a mini-slot instead of only at the beginning of a slot in the slot-based transmission. A UE is configured to transmit SCI and SL-PRS in a mini-slot. There is a gap symbol between the mini-slots. Multiple UEs can be configured to start in the different mini-slots in order to multiplex the SL-PRS of the different UEs in TDM in a slot. One example of the mini-slot structure is shown in Fig. 9. There are two mini-slots in a slot. The UE1 is configured to transmit SCI1 and SL-PRS1 in the first mini-slot and the UE2 is configured to transmit SCI2 and SL-PRS2 in the second mini-slot. The mini-slot structure allows multiplexing the UEs in TDM in a slot and the multiplexed UE can transmit SCI and SL-PRS continuously without a gap in a mini-slot so that the UE does not have to carry out an additional LBT to transmit SL-PRS as if there is a gap between SCI and SL-PRS in the slot-based transmission with only one starting position for SCI. The location of the SL-PRS resource is indicated by the associated SCI transmitted at the beginning of the same mini-slot. For the slot in a dedicated resource pool where a mini-slot structure is used, the starting position and length of a mini-slot in a slot are pre-configured per resource pool.

SCI can be used to reserve SL-PRS resource in the mini-slots that are different to the mini-slot where that SCI is transmitted. SL-PRS resource can be reserved for the transmitting UE to transmit the next SL-PRS or for the receiving UE to transmit a SL-PRS to respond to the transmitting UE. In this case, SCI also indicates COT sharing whether the receiving UE can use the COT initiated by the transmitting UE to transmit the responding SL-PRS.

The mini-slot structure is also used in a shared resource pool to support SL-PRS transmission as shown in Fig. 10.

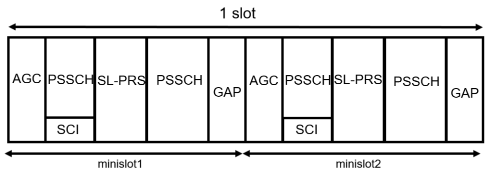


Fig. 10. The mini-slot structure in SL-PRS shared resource pool in unlicensed spectrum.

2) SL-PRS transmission with back-indication SCI in the shared resource pool in unlicensed spectrum

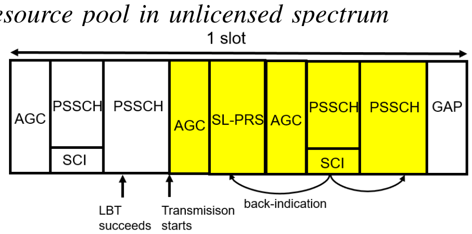


Fig. 11. SCI back-indicates SL-PRS.

In Fig. 11, in a shared resource pool, there are two starting positions with two PSCCH occasions in a slot. A transmitting UE succeeds in LBT and acquires a channel after the first starting position with PSCCH occasion and before SL-PRS occasion. To avoid wasting SL-PRS resource and latency, in the proposed scheme, the UE transmits SL-PRS without an associated SCI transmitted before to indicate SL-PRS resource. SCI transmitted in the second PSCCH occasion back indicates the location of SL-PRS transmitted in the previous symbols.

At the receiver side, the receiving UE stores the SL-PRS symbols if it does not detect SCI in the first PSCCH occasion. If the UE decodes successfully SCI in the second PSCCH occasion, it can find SL-PRS in the stored symbols based on the indication on SCI. One-bit flag is included in SCI to let the receiving UE know that SCI back indicates SL-PRS in the previous SL-PRS occasion. Based on this flag, the receiver will know when it needs to find SL-PRS in the configured SL-PRS symbols that are stored before. There is also a field in SCI to indicate frequency domain of SL-PRS transmission.

This scheme causes the higher energy and memory consumption at the receiving UE when it has to store the SL-PRS symbols if it does not detect SCI the first PSCCH occasion.

V. Numerical Results

In this section, the proposed scheme with the mini-slot structure for SL positioning in unlicensed spectrum is analyzed. In the simulation, there are 2 mini-slots in a slot in a SL-PRS dedicated resource pool. Every slot, the UEs are pre-configured to transmit SCI and SL-PRS in one of the two mini-slots. All the UEs have the same data rate. Fig. 12 shows the percentage of blocking probability improved when a mini-slot structure is used compared to when a SL-PRS slot-based transmission is used. As shown in Fig. 12, when there are 4 UEs in the system and data rate is 0.01, blocking probability reduces by 2% compared to the slot-based transmission. When the number of UE and data rate increase, blocking probability is improved further by using the mini-slot structure. For example with 10 UEs and data rate of 0.03, blocking probability reduces by 10%.

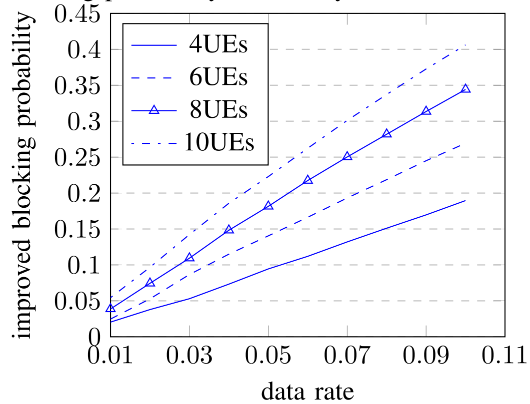


Fig. 12. Improved blocking probability in the mini-slot structure.

One disadvantage of the mini-slot structure is that the receiving UE must search blindly for SCI on a mini-slot level instead of a slot level. It increases the number of blind decoding attempts leading to a higher power consumption.

VI. Conclusion

NR SL positioning has been introduced in Release 18 to enhance NR SL communication with a location service. In this article, the scenarios and requirements of NR SL positioning are provided. Subsequently, positioning and measurement methods used in the supported scenarios are presented. To satisfy the requirements and integrate SL positioning in NR SL communication, new physical layer features for SL positioning have been specified in Release 18. This article describes the standardized features of the SL-PRS transmission. The proposed features of SL-PRS in unlicensed spectrum in the future Release 19 are also provided.

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