# Continuous Steering Backups of NLoS-Assisted mmWave Networks to Avoid Blocking

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***Abstract*—Millimeter wave (MMW) communication constitutes a fundamental technology in next-generation networks. However, with high propagation loss and unfavorable atmospheric absorption, MMW systems are highly susceptible to blocking MMW nodes, thus requiring frequent re-steering of highly directional antenna beams to establish and maintain links disrupted by link blockage or beam misalignment. Consequently, setting up a backup communication link in an MMW network involves creating a redundant connection that can be used as an alternative when the primary link experiences difficulties. This is essential to ensure continuous communication and minimize downtime in the MMW network. This paper proposes a vision-assisted beam-steering framework for steering both line-of-sight (LoS) and non-line-of-sight (NLoS) beams in addition to setting up a backup communication link that uses NLoS paths for data communication during blockage events. Visual information captured by cameras mounted on the MMW BS can effectively reflect the sizes and locations of the environmentally scattered objects and thereby can be used to infer communications parameters like propagation, and blockage characteristics. In addition to the need for steering the LoS beam toward the mobile at a certain angle for beam-steering, here we propose the need for steering the backup NLoS beam reflected from the surrounding building surface toward the mobile at another certain angle to avoid disconnection during temporary blockages.**

***Index Terms*—Millimeter wave (MMW) communication, vehicle-to-everything (V2X) networks, beam steering, backup link, overcoming link blockage, sensor data aids MMW communication.**

## I. INTRODUCTION

Millimeter wave (MMW) communication systems use highly directional beams to combat high path loss [1]. Adaptive beam steering is crucial to maintain the LoS link even as mobile devices or obstacles move. The base station (BS) and the mobile typically employ their beams in the line of sight (LoS) direction to maximize link strength for high data rate communication. As devices move, the system needs to continuously track and adapt the beam direction to maintain the LoS link. As shown in Figure 1(a), physical obstacles between the BS and the user equipment (UE) completely block the narrow directional link between the BS and the UE, causing a link outage and significant overhead by attempting to reestablish the connection [1]. For instance, the initial access procedure in 5G new radio involves sweeping broadcast information in 64 beams every 20 ms to discover either LoS or non-line-of-sight (NLoS) paths, which results in delay discovery time can take up to 1.28 seconds [2]. This not only consumes significant power but also affects interference. Blockage by physical obstacles is a significant challenge in outdoor MMW communication systems, and addressing this issue is crucial for the efficient utilization of unlicensed spectrum and ensuring reliable connectivity. Solutions to this issue may include the use of high-sensitivity receptors, high transmission power, or the use of NLoS ground reflection signals which can rescue MMW links during random and unpredictable blockage Scenarios [3]. However, due to the sophisticated and expensive equipment required, increasing receiver sensitivity and the transmit power beyond a given limit may not be practical. As shown in Fig. 1(a), NLoS beams reflected from the ground propagate randomly and non-directionally toward the target. Furthermore, the incidence angle of the LoS beam direction and the incidence angle of the ground-reflected NLoS path propagation are quite similar. Therefore, there is a high probability that the same obstacle can block both LoS beams and ground-reflected NLoS beams simultaneously. This is due to the natural characteristics of high-frequency propagation, which make it easily susceptible to being blocked by obstacles [1]. All these impairments give rise to the use of NLoS as a backup link, especially when there is precise steering of the beam and a path different from that of the LoS link.

It has been demonstrated by several studies [4], [5] that mmWaves transmitted signals, such as reflections from nearby infrastructures can help partially extend the coverage area of BS. Signals that encounter obstacles like buildings, walls, or other structures can reflect off these surfaces, creating multiple paths for the signal to reach the receiver. On the other hand,

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This work was supported in part by the Institute of Information & Communications Technology Planning & Evaluation (IITP) under a grant (No. 2021-0-02208) and the National Research Foundation of Korea (NRF) under a grant (No. 2022R1A5A1027646) funded by the Korea government [Ministry of Science and ICT (MSIT)].

(a) A conventional scenario involves steering only LoS without backup.

(b) The proposed scenario involves steering both LoS and NLoS with (NLoS) backup.

Figure 1: Comparison of scenarios.

there have been attempts to integrate sensing functionality to aid communication [6]. To exploit visual information, some researchers have studied vision-assisted beamforming methods for MMW communications, which is related to this work [7]. Vision-aided beam selection and blockage prediction for MMW communications are described in [8]. Our work introduces novel camera-assisted beam alignment in MMW communications for both LOS and backup NLoS for redundant connection links. Most of the previous research in this field focused on identifying and preventing NLOS [9]. In this paper, we investigate new steering algorithms to take advantage of the NLOS propagation paths as a backup to LoS rather than canceling them. The ability of electronic beamforming for real-time adjustment of beam direction can assist in sustaining a communication link by using alternate NLoS paths when the direct LoS beam is blocked [10]. The NLoS path can be steered toward the target using the reflection mechanism to adjust beam direction by controlling the angle of incidence on the surfaces of surrounding buildings. Pre-calculated beamforming patterns (codebook) can be used, with each pattern representing a specific direction in which the transmission or reception beam can be focused [4].

As depicted in Fig. 1(b). In contrast to conventional solutions, which aim to identify and mitigate NLOS impact, we propose exploiting the NLoS beam by providing NLoS paths backup that has the property of steering toward the target in a different direction than that of the LoS paths used. Simulation results demonstrated that steering backup NLoS paths between the BS and the UE is helpful for maintaining control plane communication and time synchronization between the BS and the UE, enabling the UE to maintain control over a temporary blockage. This then can help speed up the recovery of the LoS link as soon as the blockage clears result, resulting in reduced overhead expenses. Our simulations revealed that the RSS on the NLoS path is approximately 9 dB lower than the LoS path in an outdoor environment. This is sufficient to maintain the NLoS connection over which the control packets are passed.

## II. SYSTEM MODEL

### A. *Problem Formulation*

During blockage events, poor received signal strength (RSS) causes link outages. In the conventional solution, to continue communication with the network, the UE is left with one of two options [9]. One alternative is to perform a handover to a neighboring BS. The second alternative is to switch to the NLoS path if such a path exists between the BS and UE. In the signal obstruction scenario, the reflected NLoS beam density and trajectory between the BS and the EU typically depend on the size and type of the obstacle. With a small obstruction, the mmWave signal can still find alternative paths by reflecting off surfaces, diffracting around objects, or scattering in various directions [4]. The UE initiates measurement schedules where it systematically scans different angular directions or specific beams to search for available NLoS paths [10]. Link blockage is a sudden and unpredictable event so the UE must always have an alternative NLoS link on hand.

The BS and UE need to continuously adjust their respective directional radio beams to maintain highly aligned LoS beams. However, in a mobility scenario, beam adaptation is a challenging task that necessitates multiple measurement opportunities [1]. In addition, without a backup NLoS link, the EU needs to discover the available NLoS path, which leads to significant additional measurement opportunities [11]. Whenever the BS adjusts the transmit beam to prevent user mobility, the mobile must implement a full spatial scan to discover new NLoS paths. During user mobility, the NLoS path discovery process is frequently performed in order to adapt the transmit beam. Since the BS is responsible for scheduling measurement opportunities for all users, frequent ambient scans have a negative impact on overall network performance [11]. A link outage occurs if there is no NLoS path available to the mobile during a blockage event, and the mobile is disconnected from the BS. Afterward, the UE must perform an initial network access process as if it were a new device. In the same way, the UE will also have to follow the same process when handing over to a neighboring BS [4]. An obstacle may suddenly block the LoS link, causing sudden drops in the RSS level. At this point, with our protocol, neither a handover procedure nor NLoS path discovery is required in the UE. As illustrated in Fig. 1(b), in a sudden block of the LoS link, the mobile needs to switch to receive the redundant NLoS reflected from the surrounding building, which is continuously steered towards the UE during the connection time from a different direction from the LoS link.

### *B. Signal and Channel Model*

We consider the MMW vehicle-to-infrastructure (V2I) communication system [2], where a vision camera is mounted on the MMW BS. The objective of the system we want to design is to steer LoS and NLoS beams in addition to providing a backup NLoS link in a communication network that serves as a redundant LoS link based on information extracted from the vision camera. We consider a downlink orthogonal frequency-division multiplexing (OFDM) MMW system beamforming [12], in which the BS is located on the street curb and serves a UE in its coverage area using $N_c$ subcarriers. Each of the transmitter and receiver ends is fitted with antenna arrays with a single radio frequency (RF) chain and identical complex beam codebooks $\mathcal{C}_t = \{\mathbf{f}_i\}_{i=1}^{C_t}$ and $\mathcal{C}_r = \{\mathbf{w}_j\}_{j=1}^{C_r}$, respectively.

We assume the frequency-fiat channel model as in [16] for LoS and backup in $ith$ and $jth$ arrays, respectively.

$$\begin{cases}\mathbf{H}_{\text{LoS},i} = \sqrt{\frac{N_{\text{BS}} N_{\text{V}}}{W_i}} \sum_{w=1}^{W_i} \alpha_{i,w} (\theta_{i,w}^{\text{v}}, \phi_{i,w}^{\text{v}}) (\theta_{i,w}^{BS}, \phi_{i,w}^{BS}), \\ \mathbf{H}_{\text{Backup},j} = \sqrt{\frac{N_{\text{BS}} N_{\text{V}}}{W_j}} \sum_{w=1}^{W_j} \alpha_{j,w} (\theta_{j,w}^{\text{v}}, {}_{j,w}^{\text{v}}) (\theta_{j,w}^{BS}, {}_{j,w}^{BS}). \end{cases} \tag{1}$$

$W_i$ and $W_j$ are the number of paths, corresponding to the complex gain $\alpha_i$ and $\alpha_J$, respectively. $(\theta_{i,w}^{\text{v}}, \phi_{i,w}^{\text{v}})$ and $(\theta_{i,j,w}^{BS}, \phi_{i,j,w}^{BS})$ are the receive and transmit array response vectors for LoS and backup, consecutively.

The downlink channel matrix for LoS and backup NLoS link from the BS to the vehicle through the $n_{th}$ subcarrier can be written as

$$\begin{cases}\mathbf{H}_{\text{Los},i} = \partial_{\text{BS}}^{LoS} \mathbf{H}_{\text{v},i}^{LoS} \partial_{\text{V},i}^{LoS*}. \\ \mathbf{H}_{\text{ Backup },J} = \partial_{\text{BS}}^{Backup} \mathbf{H}_{\text{v},J}^{Backup} \partial_{\text{V},J}^{Backup*}. \end{cases} \tag{2}$$

Where the directional vector matrices $\partial_{\text{BS}}^{LoS}$ and $\partial_{\text{V},i}^{LoS}$ include the BS and vehicle array response vectors assessed on the grid of channel estimation of the angles of arrivals/departures (AoAs/AoDs). $\mathbf{H}_{\text{v},i}^{LoS}$ and $\mathbf{H}_{\text{v},J}^{Backup}$ denote path gains associated with (Aids) and (AiDs). The received signal at time k at the $ith$ $jth$ and phased array for LoS and backup line in the vehicle is given by

$$\begin{cases}\text{x}_i^{LoS}[k] = \mathbf{H}_{\text{Los},i} \mathbf{f} s[k] + \mathbf{n}_{\text{d},i}[k], \\ \text{x}_j^{backup}[k] = \mathbf{H}_{\text{ Backup },J} \mathbf{f} s[k] + \mathbf{n}_{\text{d},j}[k]. \end{cases} \tag{3}$$

Where $\mathbf{f} = \mathbf{F}_{\text{RF}} \in \mathbb{C}^{N_{\text{BS}} \times L_{\text{BS}}} \mathbf{f}_{\text{BB}} \in \mathbb{C}^{L_{\text{BS}} \times 1}$ is the BS a hybrid precoder, $\mathbf{n}_{\text{d},i}[k]$ and $\mathbf{n}_{\text{d},J}[k]$ refer to white Gaussian noise vectors at the $ith$ and $jth$ phased arrays, respectively.

With respect to each pair of precoder and combiner vectors $(m, n) \in \mathcal{C}_t \times \mathcal{C}_r$. Without loss of generality, we suppose a power transmission unit on each sub-carrier with a unit noise variance. Thus, the power received over all subcarriers for the transmitter-receiver codebook pair $(m, n)$ can be denoted as

$$\begin{cases}\mathbf{P}_{m,n}^{LoS} = \sum_{n=1}^{C} |\mathbf{w}_i^{\mathbf{H}}{}_{\text{Los},n} \mathbf{H}_{\text{Los},i} \mathbf{f}_m|^2, \\ \mathbf{P}_{m,n}^{backup} = \sum_{n=1}^{C} |\mathbf{w}_j^{\mathbf{H}}{}_{\text{backup},n} \mathbf{H}_{\text{backup},j} \mathbf{f}_m|^2. \end{cases} \tag{4}$$

where the maximize the receive signal-to-noise ratio (SNR) based on optimal pair of precoding and combining vectors for LoS and backup links, can be calculated as

$$\begin{cases}(m^*, n^*)^{LoS} = \underset{(m,n)}{\text{argmax}}\ \mathbf{P}_{m,n}^{LoS}, \\ (m^*, n^*)^{backup} = \underset{(m,n)}{\text{argmax}}\ \mathbf{P}_{m,n}^{backup}. \end{cases} \tag{5}$$

Without taking advantage of side information, in order to find the optimal beam pair with the highest SNR $(i^*, j^*)$ the transmitter and receiver must conduct an exhaustive search through all $C_t x \times C_r x$ beam pairs Our goals from exploiting the available position and camera data, such that $(m^*, n^*) \in \mathbb{B}_s$ are to infer a small subset of $s$ beam pairs $\mathbb{B}_s \subset \mathcal{C}_t \times \mathcal{C}_r$ for LoS, In addition to deducing and estimating the angle of incidence $\theta$ and reflection $\phi$ of the backup NLoS beam on the surface of neighboring buildings. In this context, we assume that the most appropriate location for placing MMW BS is chosen carefully in terms of proximity to buildings that can provide the maximum amount of signal reflection with minimal dispersion. This is done by relying on several factors, for example, the type of building surface if it is made of concrete or glass, surface roughness or smoothness, the height and width of the building, the extent of the flatness of the building facade, and other things. This leads to a reduction in both the search space-time for the beam selection procedure and the time for estimating the reflection angle of the backup link $\theta_i, \phi_i$ and $\theta_j, \phi_j$.

At each time instant $k$, the beamforming vector

$$\begin{cases}\mathbf{f_i}^{LoS}(k) \in \mathcal{F}_{\text{i}}, \\ \mathbf{f_j}^{backup}(k) \in \mathcal{F}_{\text{j}}. \end{cases} \tag{6}$$

is selected to maximize the average receive $SNR$ can be formulated as [12]

$$\begin{cases}\mathbf{f}_{LoS}^{i}[t] = \underset{\mathbf{f}_i[t] \in \mathcal{F}}{\text{argmax}} \frac{1}{K} \sum_{k=1}^{K} \left| \mathbf{h_{LoS}}_k^H[t] \mathbf{f}_{i\,LoS}[t] \right|^2. \\ \mathbf{f}_{backup}^{j}[t] = \underset{\mathbf{f}_j[t] \in \mathcal{F}}{\text{argmax}} \frac{1}{K} \sum_{k=1}^{K} \left| \mathbf{h_{backup}}_k^H[t] \mathbf{f}_{j\,backup}[t] \right|^2. \end{cases} \tag{7}$$

Where $\mathbf{f_i} \in \mathcal{F}_{\text{i}}$ and $\mathbf{f_j} \in \mathcal{F}_{\text{j}}$ is the optimal beamforming vector for $\mathbf{f}_i \in \mathbb{C}^{M \times 1}$ and $\mathbf{f}_j \in \mathbb{C}^{M \times 1}$, respectively.

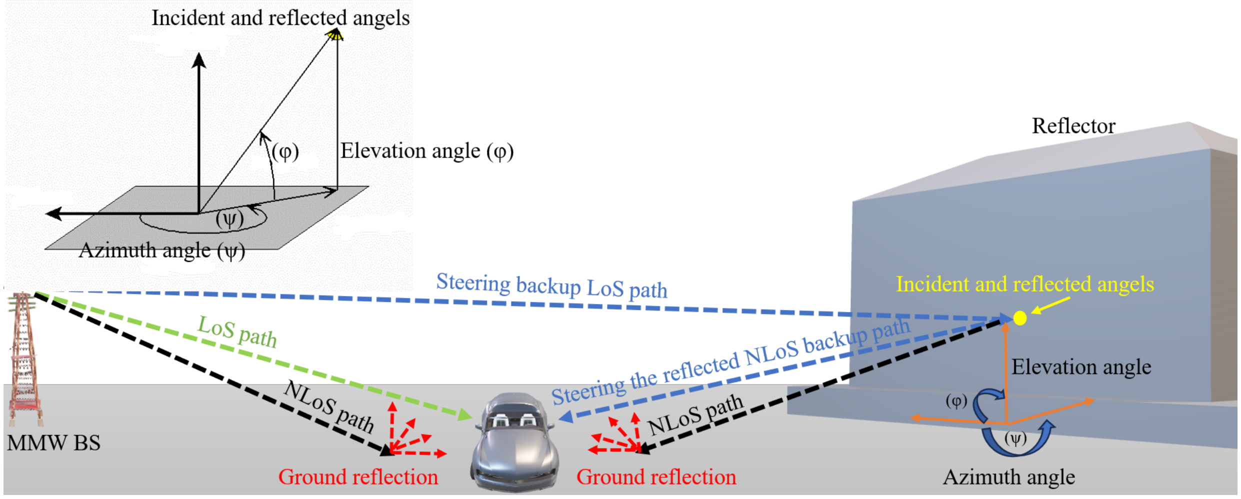


Figure 2: The proposed protocol shows the possibility of covering the recipient through one of the available paths, including the LoS path, the ground-reflected path, and the backup NLoS path.

### *C. NLoS beam steering*

This subsection discusses how the steering reflected beam algorithm directs the reflected NLoS beam toward the target throughout the connection duration. The incidence angle is determined in the specific case of anomalous reflection on the surface of neighboring buildings for beam steering. Indeed, MMW signals exhibit distinctive behaviors when interacting with a variety of surfaces, including concrete and glass.

Understanding how MMW signals reflect on these surfaces is crucial to designing effective communication systems, especially in urban environments. Concrete surfaces, particularly when smooth, can cause specular reflection. This means the signals bounce off the surface like a mirror, maintaining their original direction. In this context, it is important to estimate a certain angle for incidence on the surface. The incidence angle refers to the angle at which the signal hits the surface to steer the reflected signal in a specific direction. Note: The angle of incidence equals the angle of reflection. In urban environments, where concrete and glass surfaces are abundant, signals can experience multiple reflections. Communication systems can leverage reflections to steer beams around obstacles and maintain connectivity through alternate paths. Reflections can enhance signals at certain locations, compensating for blockages. As we indicated earlier, the most appropriate location for placing MMW BS should be chosen carefully in order to maximize signal reflection and minimize signal dispersion. Several factors are considered, such as the type of building surface, which may be made of concrete or glass, surface roughness or smoothness, the height and width of the building, and the degree of flatness of the facade.

As indicated in [13], steering of the reflected signal in a certain direction can be obtained by implementing phase gradients. Here, the values of each parameter of conduct must be adjusted for a reflection phase with linear gradients $\psi'_x$ and $\psi'_y$ in the directions $x$ and $y$ , respectively.

The result is that the phase of a beam steering parameter at location $(i, j)$, can be written as.

$$\psi_{ij} = (\psi'_x i + \psi'_y j)\delta, \tag{8}$$

where the actual phase is mapped to that of the closest state [16] with the size of $\delta$. The momentum conservation law for wave vectors can be utilized to relate the target reflected angle $\{\varphi_r, \psi_r\}$ in polar coordinates with the angle of incidence $\{\varphi_i, \psi_i\}$ and the phase gradients ($\psi'_x$ and $\psi'_y$), result in

$$\begin{cases} \psi'_x = \tau_r \sin\varphi_r \cos\psi_r - \tau_i \sin\varphi_i \cos\psi_i \\ \psi'_y = \tau_r \sin\varphi_r \sin\psi_r - \tau_i \sin\varphi_i \sin\psi_i. \end{cases} \tag{9}$$

Where wavelengths $\lambda_i$ and $\lambda_r$ are applied to $\tau_i = \frac{2\pi}{\lambda_i}$ and $\tau_r = \frac{2\pi}{\lambda_r}$, which are the wave vectors of the incident and reflected angels.

The proposed scenario involves a transmitter and receiver establishing a reliable communication channel via the LOS beam and the backup NLOS beam concurrently during the connection duration. The objective is to provide a continuous backup NLOS link by creating a redundant connection that can be used as an alternative when the primary LOS link experiences issues. We consider the scenario depicted in Fig. 2, where two beams emanate from an MMW BS. One of the beams is a LoS beam with ground-reflected signals, and the second beam is a backup NLoS beam with ground-reflected signals. At a certain angle, the backup NLoS beam is incident on the surrounding building surface. A combination of azimuth and elevation angles is used in order to precisely steer the NLoS reflected beam towards the receiver. These angles are controlled by adjusting the phases and amplitudes of the signals from different antennas in an antenna array. By carefully adjusting these angles, the system can determine the optimal angle of reflection that leads to directing the beam toward the target. In a general sense, we assume the beam is reflected on the building surface at a specific angle of reflection corresponding to the elevation and azimuth components of $\varphi_r(t)$ and $\psi_r(t)$ respectively, at each time instance $k$.

The vectors are used to create a beamforming codebook by incorporating incidence and reflection angles $\psi_i = [\varphi_i, \psi_i]$, $\psi_r = [\varphi_r, \psi_r]$ , respectively. The reflection angle $\psi_r$ depends on the incidence angle and type and roughness of the surface. The LoS, ground-reflected, and the backup NLoS paths distance can be formulated as

$$\begin{cases} \mathrm{LoS}_d = \sqrt{(e_{tx}-e_{tr})^2+(P_d)^2}, \\ \mathrm{Gr}_d = \sqrt{(e_{tx}-e_{tr})^2+(p_r)^2}, \\ \mathrm{Bu}_d = \sqrt{(e_{tx}-e_{tr})^2+(P_d-p_r)^2}. \end{cases} \tag{10}$$

Where $e_{tx}$ and $e_{tr}$ are the heights of the transmitter and receiver, respectively. $P_d$ and $p_r$ denote the direct and reflected beams measured, correspondingly.

### *D. Reflection characteristics*

Reflection of MMW signals on different surfaces, such as concrete and stained glass, exhibits distinct characteristics due to their material properties and surface conditions. Concrete surfaces typically have a relatively smooth and rigid structure, which can lead to significant signal reflection. The smooth surface allows for specular reflection, where the incoming signal bounces off the surface at the same angle of incidence. Stained glass can have varying levels of reflectivity depending on its transparency, color, and texture. Clear or lightly colored stained glass may allow more transmission of signals, while more opaque or colored glass can lead to greater reflection.

## III. Results And Discussion

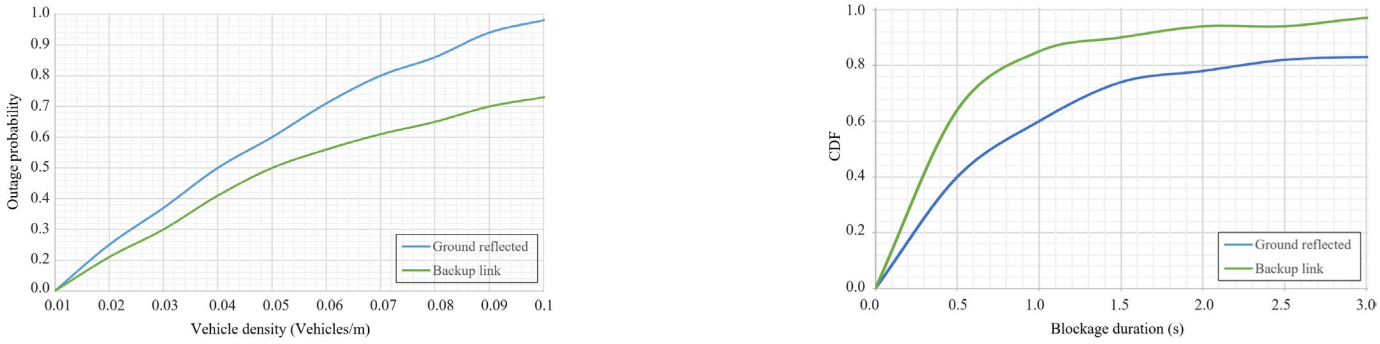
In order to evaluate the performance of the proposed algorithm, the simulation platform is designed and performed for the MMW V2I communication system in urban scenarios. The deep learning dataset framework for vision-aided wireless communications (ViWi) dataset [14] is used in this simulation to capture virtually with high-fidelity V2X deployment in the urban environment. To address a vision-wireless problem, it is necessary to define the physical environment where it will be studied, which is known as the scenario definition.

This description should identify both visual instances of the scenario and electromagnetic elements. Game engine software is used to build and assemble visual elements such as buildings, curbs, streets, cars, trees, people, etc. The same scenario definition with its visual elements is constructed in ray-tracing software [15] in order to define the electromagnetic characteristics of the scenario. In the simulation scenario, the MMW BS is fitted with a total of 3 cameras that are 5 meters high. Each camera has a field of view of 100 degrees. These properties were chosen to ensure that the cameras cover the entire street. In this section, the outage probability and system overhead of the proposed model are analyzed, and the analytical results are validated by different simulation tools. Here, we first used the camera detection method to obtain the position of the target vehicle in the scenario. Afterward, we demonstrated the accuracy of the LoS beam alignment and the incidence reflection angle of the backup NLoS beam. Ray-tracing simulations have been used to predict propagation phenomena in different settings. Highly reflective materials, such as concrete, are considered for assessing reflecting NLOS opportunities, considering urban layout. This allowed us to explore a wide range of reflection opportunities from the surrounding buildings for potential backup NLOS transmission paths. Fig. 3(a), shows the outage probability as a function of vehicle density (vehicles/m), during a vehicle blockage that lasts for about 100ms. The receiver was unable to decode the transmitted information, leading to an outage during this event. However, the ground-reflected beam did not suffer an outage in the case of low vehicle density. In this particular experiment trial on a concrete surface, the received signal strength was -64 dBm in the ground reflected direction and -60 dBm in LoS. Our vehicle blockage experiments were repeated with different blockage probabilities. There is a direct correlation between vehicle density and outage probability. As a result, the higher the density of vehicles, the higher the probability of a link outage. Both the ground-reflected beam NLoS and LoS beam are significantly affected as much by the density of vehicles increasing. This is because the incidence angle of the LoS beam and the incidence angle of the ground-reflected beam are the same. Therefore, if the LoS beam is blocked, the probability of the ground-reflected beam being blocked by the same obstacle is high. On the other hand, it can be seen in Fig. 3 (a), that the proposed model is less affected by increased vehicle density. The reason for this is that the proposed model provides a backup link via a path different from the LoS beam path. Therefore, our model will provide three options for obtaining a communication link path between the main base and the user, which are the LoS path, the ground-reflected path, and the backup NLoS path.

In our second example, we investigate how the blockage duration is distributed for different blockage probabilities. As shown in Fig. 3(b), the blockage durations are significantly longer conventional method compared to our solution. The underlying reason is that, in the traditional solution, if the signal is suddenly blocked by a physical obstacle, the ground-reflected signals are often blocked too, and therefore a link outage occurs. In this scenario, the user moves from the connected to the disconnected state with the BS, and consequently, the user needs to establish the reconnection procedures as a new user, which causes significant delay and overhead. In contrast, with the same scenario, the proposed model uses the backup NLoS link to maintain control plane communication and time synchronization with the BS, enabling the UE to maintain control over a temporary blockage. This then can help speed up the recovery of the LoS link as soon as the blockage clears result, resulting in reduced overall delay and overhead expenses.

## IV. CONCLUSIONS AND FUTURE WORK

The presence of obstructions causes dramatic drops in channel quality due to the high attenuation in the MMW band. In addition, users may experience a significant drop in



(a) Outage probability as a function of vehicle density.

(b) The cumulative distribution function (CDF) of the blockage duration.

Figure 3: Simulation results.

their quality of service, and the re-establishment process may require significant delays and overheads. The best beam pair in the LoS scenario is distinctly superior to the others. However, blockage in the LoS might result in unexpected blockage in the NLoS beams. The proposed steering backup NLoS has shown that while a LoS path is blocked, a continuous redundant link typically can be steered toward the vehicle via a path different from the LoS path, with a loss within roughly 10 dB of the LoS path. Our proposal aims to proactively keep such a backup NLoS path in reserve, to be used when unexpected blockages occur. Steering backup NLoS uses a different path from the one that the LoS uses to maintain time-synchronization with the BS until the blockage is eliminated and to search for a more appropriate NLoS path if it's available. Once the transient blockage disappears, LoS communication reestablishes again at the scheduled BS intervals for communication. The steering backup NLoS model is considered a dynamic blockage recovery solution with low complexity and power efficiency. Simulation evaluation in urban environments shows that the steering backup NLoS model is able to avoid outages and maintain time synchronization in 93% of the transient blockages. More interestingly, for high traffic densities with a different blockage probability, the proposed backup algorithm can reduce the average blockage duration by approximately 90% via providing continuous link backup during connection duration. Continuous backup links contribute to the overall resilience of the communication system, making it ensures that communication remains functional even if the primary LoS link experiences temporary outages. The future work involves the design of a speed-up protocol for automatically switching to the redundant link if the primary LoS link experiences issues such as blockage, interference, or other disruptions, in the system.

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