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Prior information based channel estimation for millimeter-wave massive MIMO vehicular communications in 5G and beyond

Key words: Massive multiple-input multiple-output; Millimeter wave; Channel estimation; Vehicular communication; Time-varying

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Motivation

- To realize reliable communications in fast mobility scenarios, such as on high-speed vehicles, future millimeter-wave (mmWave) massive multiple-input multiple-output (MIMO) wireless communication (the emerging 5G and beyond) networks of connected vehicles are desired.
- Vehicular networks operate under more severe conditions than common cellular networks due to the time-varying channel, which significantly reduces the coherence time.
- Existing schemes are unrealistic in a dynamic environment since user mobility leads to a fast variation channel.

Motivation (Cont’d)

- The high mobility feature of vehicles further increases the frequency of channel estimation.
- It is particularly difficult to achieve high beamforming, because the beamforming process must be completed in a highway scenario.

Main idea

- The conventional spatial domain is transformed into an angular domain by discrete lens array (DLA), which effectively reduces the number of required RF chains and the dimension of the MIMO system.
- We have exploited the derived temporal variation law and the moving position vector of users in the time-varying channel to estimate the direction-of-arrival (DOA) of multiple moving users.
- Based on the principle that the actual space direction is approximately equal to the predefined one, the time-varying physical direction can be determined and further refined. It can adaptively adjust the residual caused by the moving direction and speed.

Main idea (Cont'd)

- The complete time-varying channel has been estimated using the prior information (PI) with low pilot overhead.
- Our method can accurately estimate the line-of-sight (LoS) paths between the base station (BS) and multiple fast-moving users in the vehicle-to-infrastructure (V2I) communication scenario, which makes it attractive for fast time-varying mmWave vehicular communication systems.

Method

- By considering the fast moving vehicle scenario, a mathematical model is first established for the fast time-varying channel.
- We have exploited the derived temporal variation law and the moving position vector of users in the time-varying channel to estimate the DOA of multiple moving users.
- The temporal variation rule between the BS and each mobile user is derived, based on which and the determined time-varying physical direction in the previous time slots, the physical direction in the subsequent time slot can be successfully predicted.

Method (Cont’d)

- The PI of the time-variant channel in the next time slot can be predicted by exploiting the estimated physical direction and the special sparse structure of the channel.
- The time-varying channel can be estimated using PI.

Major results

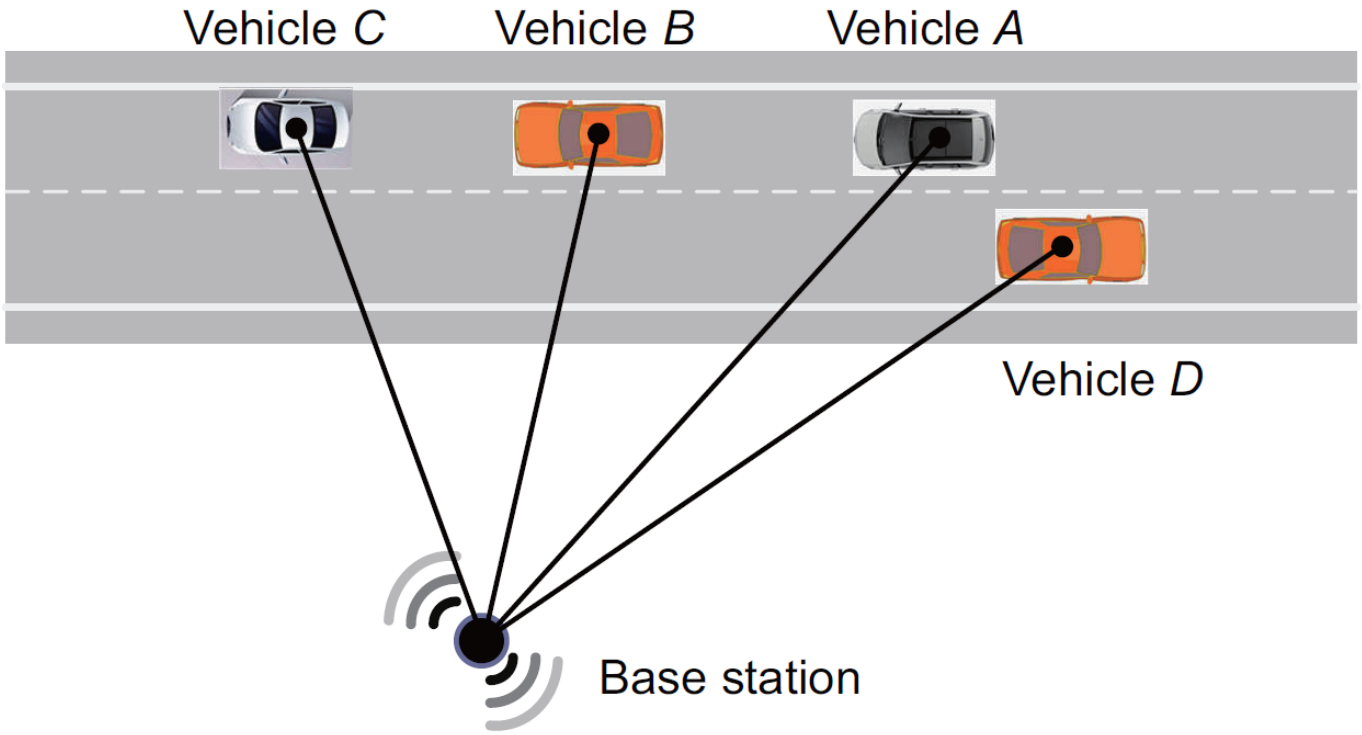

Fig. 1 An mmWave vehicle-to-infrastructure (V2I) fast vehicular communication system model

Major results (Cont'd)

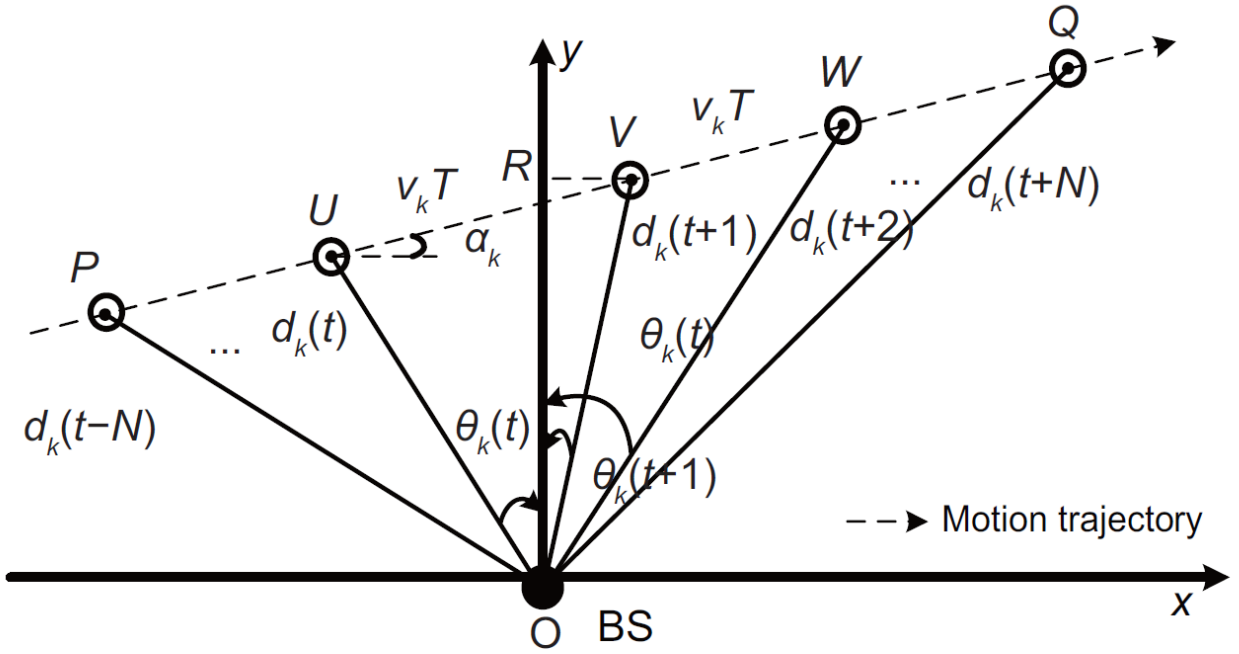

Fig. 2 Location relationship model between the base station (BS) and the movement trajectory of the k^{th} mobile user

Major results (Cont'd)

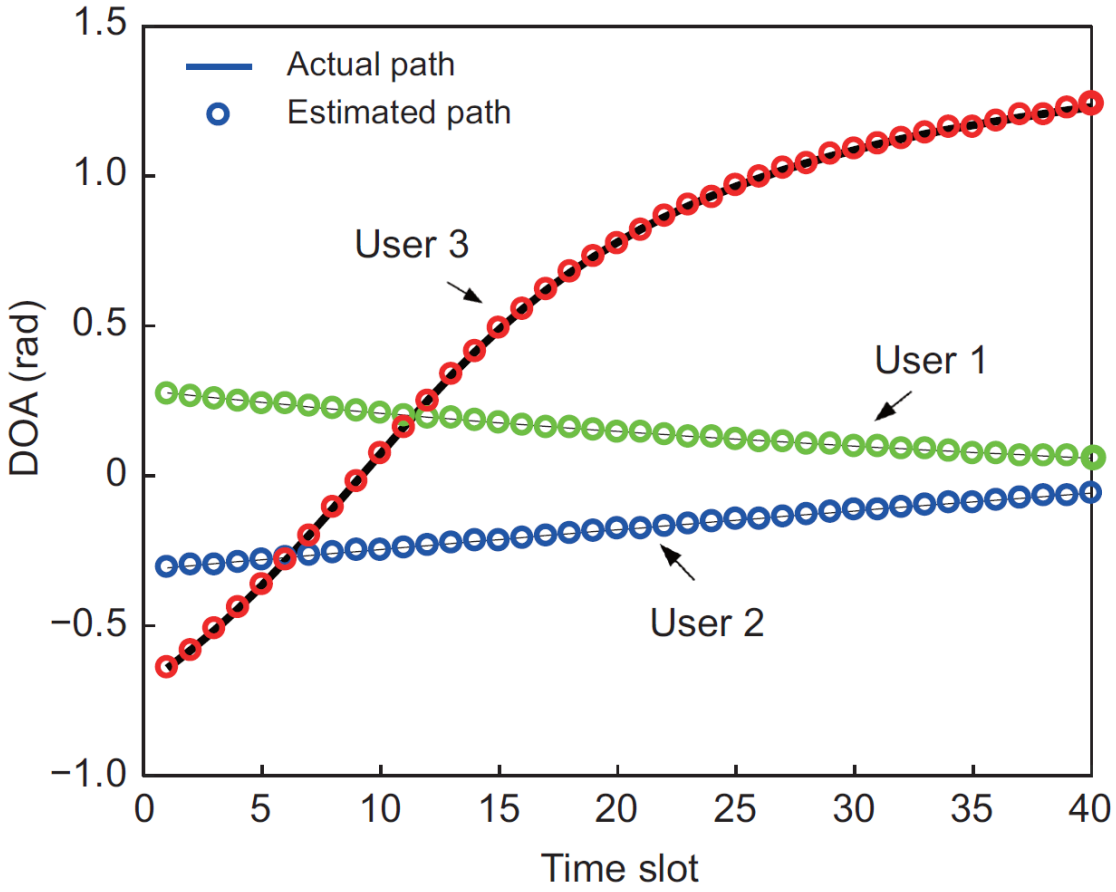

Fig. 3 DOA estimation performance of our method with SNR=10 dB and Q=16

Major results (Cont'd)

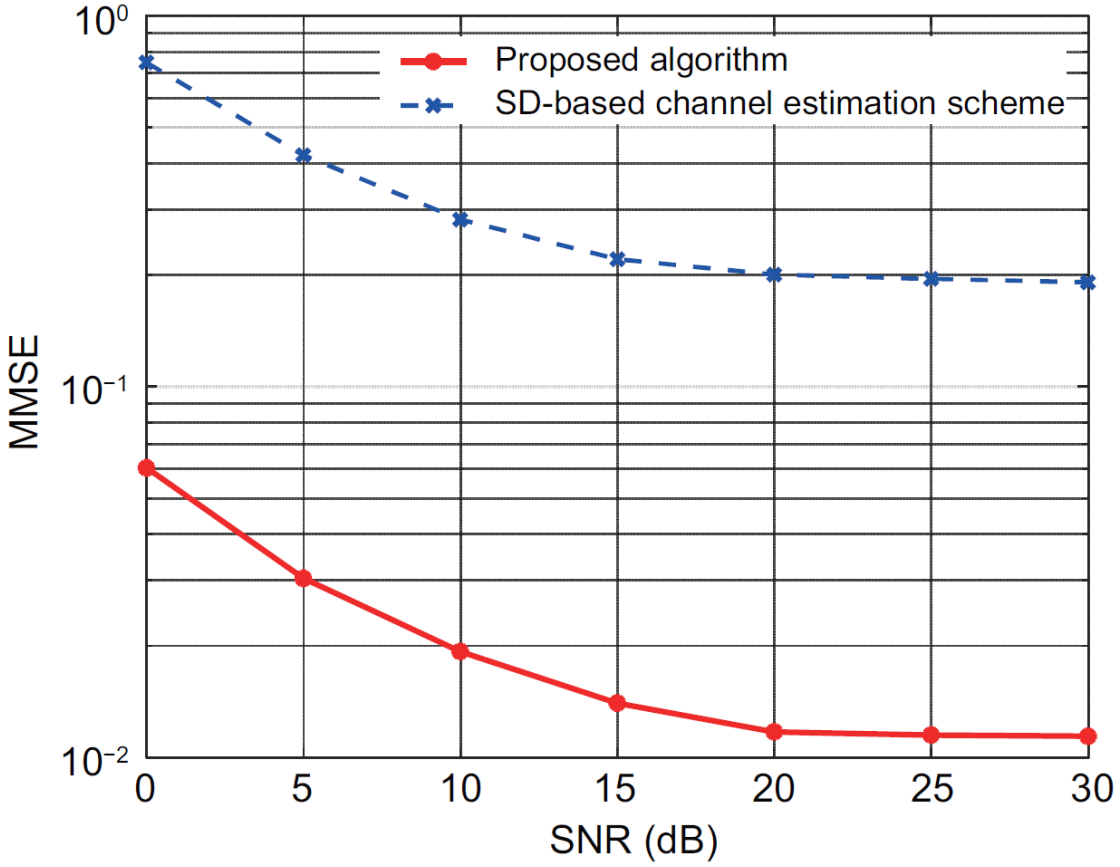

Fig. 4 NMSE comparison between the SD-based channel estimation and the proposed scheme

Major results (Cont'd)

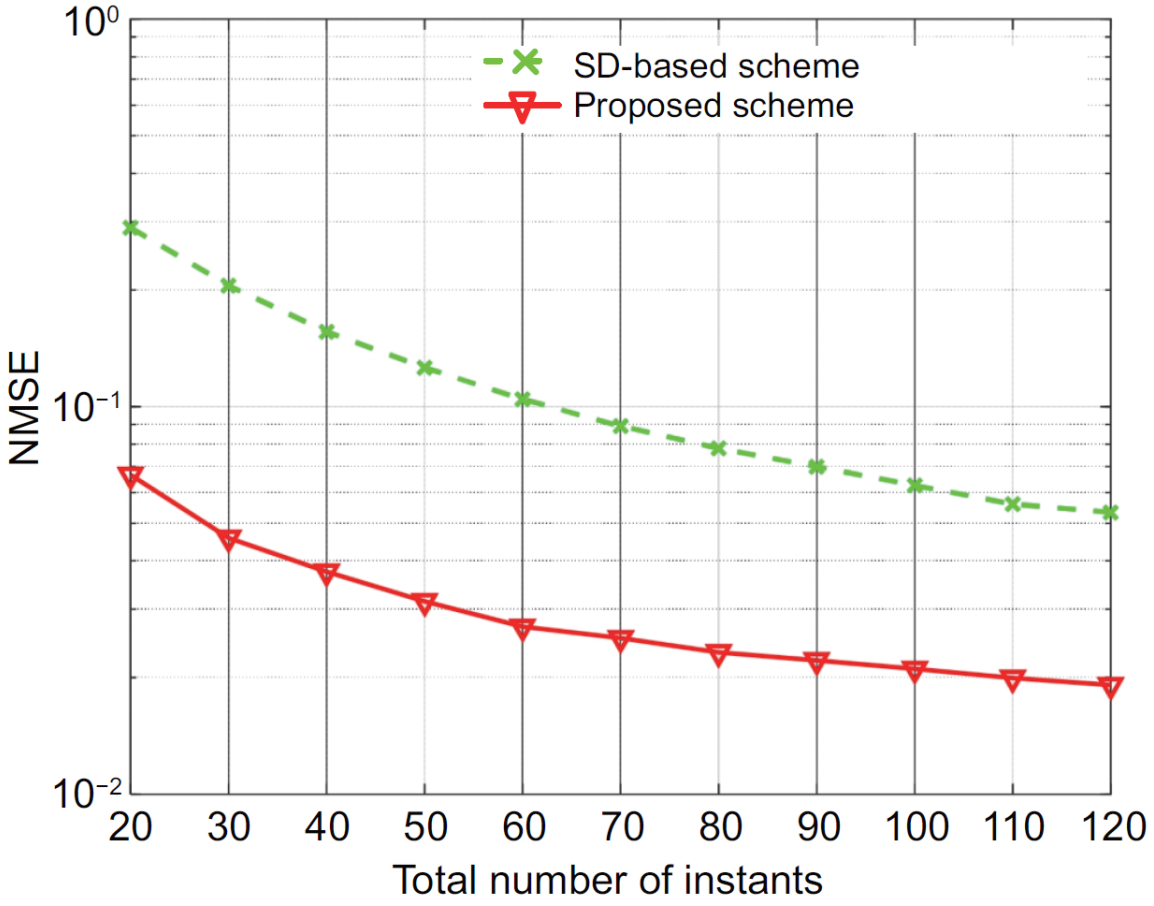

Fig. 5 NMSE performance comparison against the total number of instants Q for pilot transmission

Major results (Cont'd)

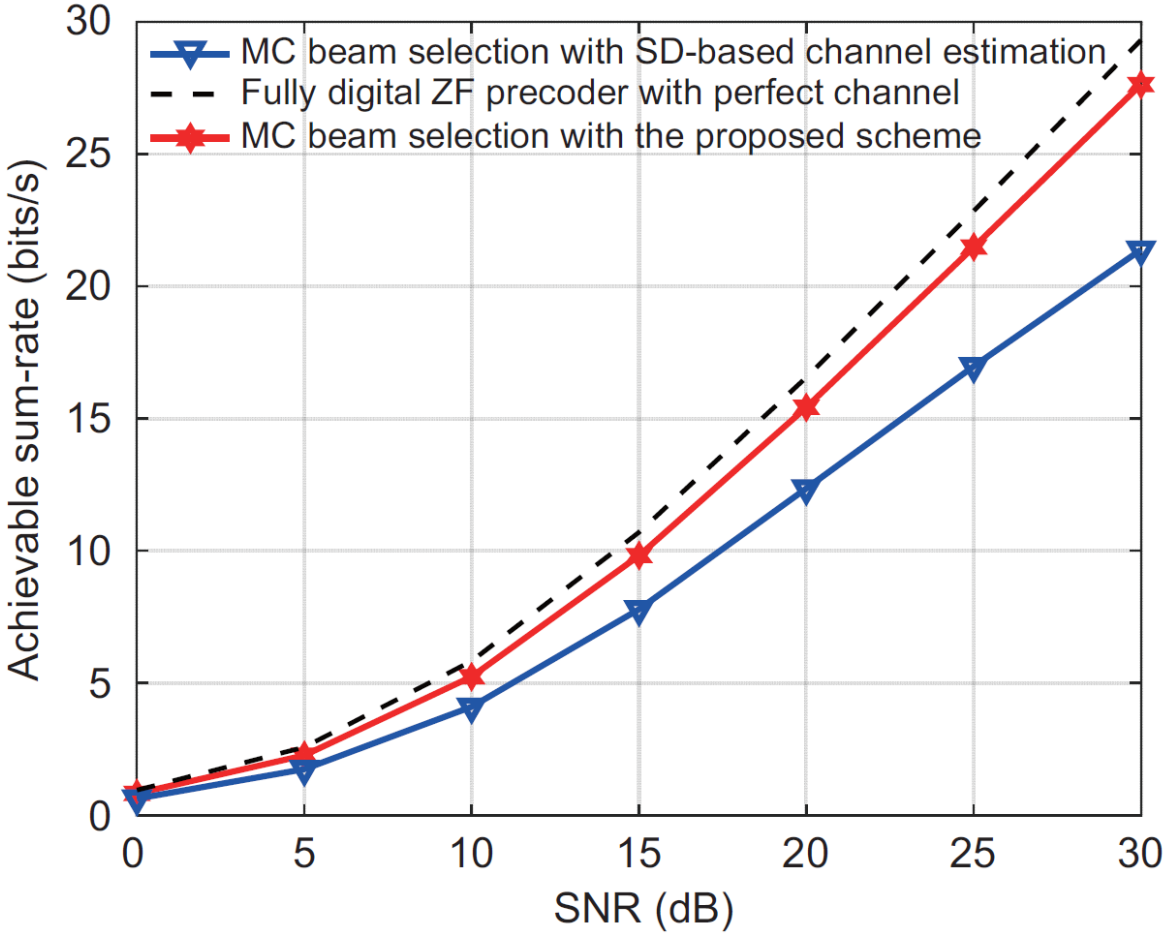

Fig. 6 Sum-rate performance comparison between MC beam selection with different channels

Conclusions

- We propose a novel PI-based channel estimation scheme for the fast time-varying mmWave massive MIMO vehicular communication system, which significantly reduces the duration of channel estimation and pilot overhead, making it a viable algorithm for V2I communication scenarios.
- Our scheme can significantly improve the channel estimation accuracy and exhibit superior performance under time-varying vehicle channel scenarios. Therefore, the proposed scheme is more suitable for mmWave fast time-varying vehicle systems.
- Our method can accurately estimate the LoS paths between the BS and multiple fast-moving users in the V2I communication scenario, which makes it attractive for fast time-varying mmWave vehicular communication systems.

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