Lens-based Millimeter Wave Reconfigurable Antenna NOMA

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I. Summary

❑ **Contribution:** proposing a new multiple access technique based on the mmWave lens-based which is called RA-NOMA

❑ **Motivations and Insights:**

- Supporting a groups of users with different angles of departures (AoDs) by integrating reconfigurable antenna multiple access (RAMA) into non-orthogonal multiple access (NOMA)
- Serving users with different AoDs and comparable channel gains via RAMA
- Serving users with the same AoDs but different channel gains via NOMA
- Achieving the independence of the number of radio frequency chains from the number of NOMA groups

II. Background: RAMA

❑ **The downlink of a mmWave system with single base station and several mobile users with different AoDs is assumed as follows.**

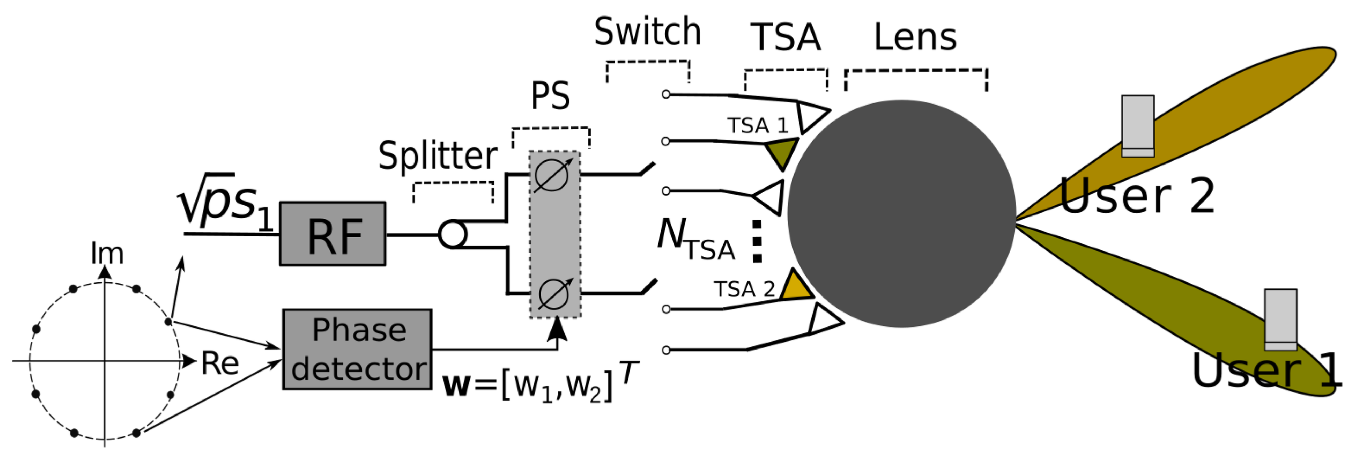

Fig. 1. Schematic of RAMA for two users [1].

❑ **The Achievable Rate:**

- Channel model: $\mathbf{a}(\theta,\phi)=\frac{1}{\sqrt{N_{\text{ray}}}}\left[1,\dots,e^{-j\pi\psi_{r,s}},\dots,e^{-j\pi\psi_{N_{\text{ray},x}-1,N_{\text{ray},y}-1}}\right]^T$
- Signal model: $\mathbf{s}=\mathbf{w}s_1$, where $\mathbf{s}=\mathbf{w}s_1$, and $\mathbf{w}=\left[1,e^{j\Delta\theta}\right]^T$
- Received signal: $\begin{cases} y_1=\sqrt{p_1}h_1s_1+n_1 \\ y_2=\sqrt{p_2}h_2s_2+n_2 \end{cases}$
- Achievable rate: $\begin{cases} R_1=\log_2(1+\frac{p_1|h_1|^2}{\sigma_n^2}) \\ R_2=\log_2(1+\frac{p_2|h_2|^2}{\sigma_n^2}) \end{cases}$

III. The Proposed RA-NOMA Technique

❑ **The Proposed RA-NOMA:**

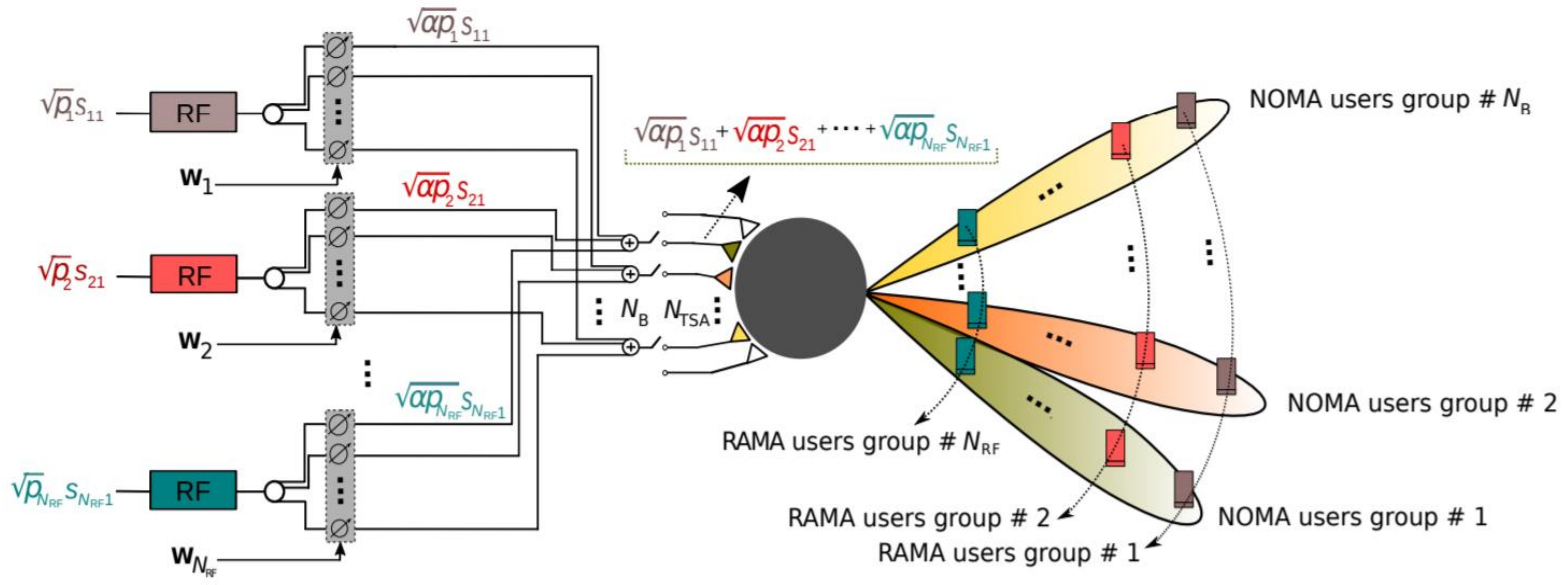

Fig. 2. The proposed RA-NOMA technique.

- The users are grouped into RAMA users and NOMA users.
- The number of RAMA groups is equal to the number of RF chains and the number of NOMA groups is the same as the number of beams.
- The number of beams is independent of the number of RF chains.

❑ **The Achievable Rate:**

- Signal model for the users in the ith RAMA group: $\mathbf{s}_i=\mathbf{w}_is_{i1}$, where $\mathbf{s}_i=[s_{i1},\dots,s_{iN_B}]^T$ and $\mathbf{w}_i=[1,e^{j\Delta\theta_{i2}},\dots,e^{j\Delta\theta_{iN_B}}]^T$
- The superposition coded signal of the kth beam: $\sum_{i=1}^{N_{\text{RF}}}\sqrt{\alpha p_i}s_{ik}=\sqrt{\alpha p_1}s_{1k}+\dots+\sqrt{\alpha p_{N_{\text{RF}}}}s_{N_{\text{RF}}k}.$
- The received signal by User (i,k): $y_{ik}=\underbrace{\sqrt{\alpha p_i}h_{ik}s_{ik}}_{\text{intended signal}}+\underbrace{\sum_{l=1,l\neq i}^{N_{\text{RF}}}\sqrt{\alpha p_l}h_{ik}s_{lk}}_{\text{intra-beam interference}}+\underbrace{n_{ik}}_{\text{noise}}$
- The achievable rate of User (i,k): $R_{ik}=\log_2\left(1+\frac{\alpha p_i|h_{ik}|^2}{|h_{ik}|^2\sum_{l=i+1}^{N_{\text{RF}}}\alpha p_l+\sigma^2}\right)$

❑ **Power Allocation:**

- Optimization problem:

$$\begin{aligned} &\underset{\mathbf{p}}{\text{maximize}} && \sum_{k=1}^{N_B}\sum_{i=1}^{N_{\text{RF}}}R_{ik} \\ &\text{subject to} && \sum_{i=1}^{N_{\text{RF}}}p_i\leqslant P_{\max}, \\ &&& R_{ik}\geqslant\bar{R}_{ik}, \quad \forall i,k, \\ &&& \mathbf{p}\geqslant\mathbf{0}, \end{aligned}$$

- The optimal power: $p_i^*=\left(\sum_{l=i+1}^{N_{\text{RF}}}p_l^*+\frac{\sigma^2}{\alpha|h_l|^2}\right)\left(2^{\bar{R}_i}-1\right)$

IV. Simulation Results

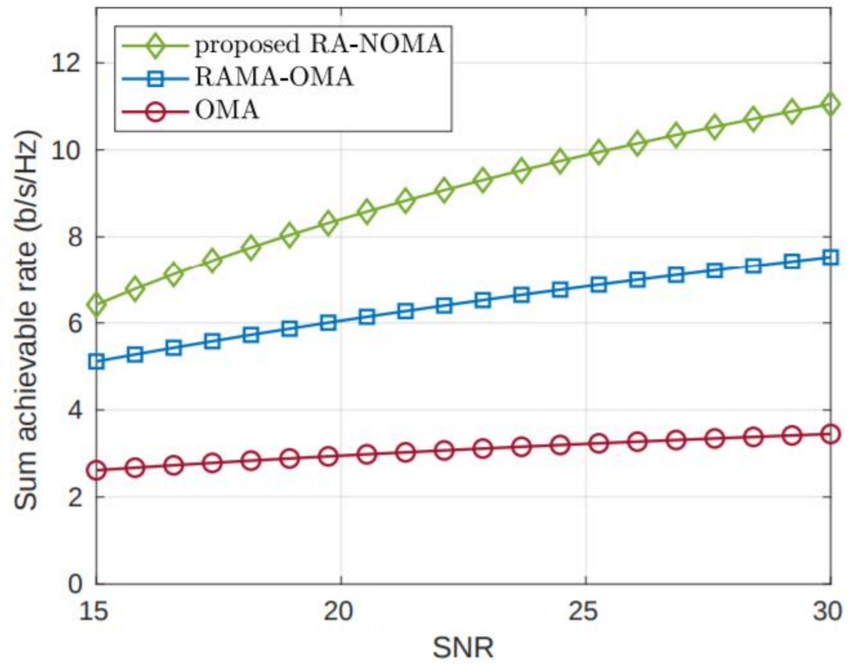

Fig. 3: Sum achievable rate of OMA, RAMA-OMA, and RA-NOMA with respect to transmit SNR.

- RA-NOMA outperforms OMA and RAMA-OMA techniques in terms of sum-rate with equal power budget at the transmitter.
- RA-NOMA is not compared with NOMA technique. This is because user grouping in RA-NOMA may not be appropriate for deploying NOMA technique.
- NOMA technique for this grouping requires four RF chains which is not efficient in terms of energy consumption and hardware expenses.

Table I: Number of required RF chains and time slots for each technique.

	OMA	RAMA-OMA	RA-NOMA
Number of RF chains	1	1	3
Number of time slots	12	3	1

V. Discussion and Conclusion

- RA-NOMA simultaneously supports a large number of users using a single BS.
- Due to the directive and independent beams steered by the lens antennas, inter-cluster interference is eliminated.
- RA-NOMA uses less number of RF chains compared to the existing mmWave-NOMA technique.
- RA-NOMA achieves higher sum-rate compared to RAMA and conventional OMA techniques.

References

[1] M. A. Almasi, H. Mehrpouyan, D. Matolak, C. Pan, and M. Elkashlan, “Reconfigurable antenna multiple access for 5G mmWave systems,” in Proc. IEEE ICCW, pp. 1–6, May 2018.

[2] K. Higuchi and A. Benjebbour, “Non-orthogonal multiple access (NOMA) with successive interference cancellation for future radio access,” IEICE Trans. Commun., vol. 98, no. 3, pp. 403–414, 2015.