Anonymous Key Agreements for V2X Communication

Gautam Singh

Indian Institute of Technology Hyderabad

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V2X Related Terminology

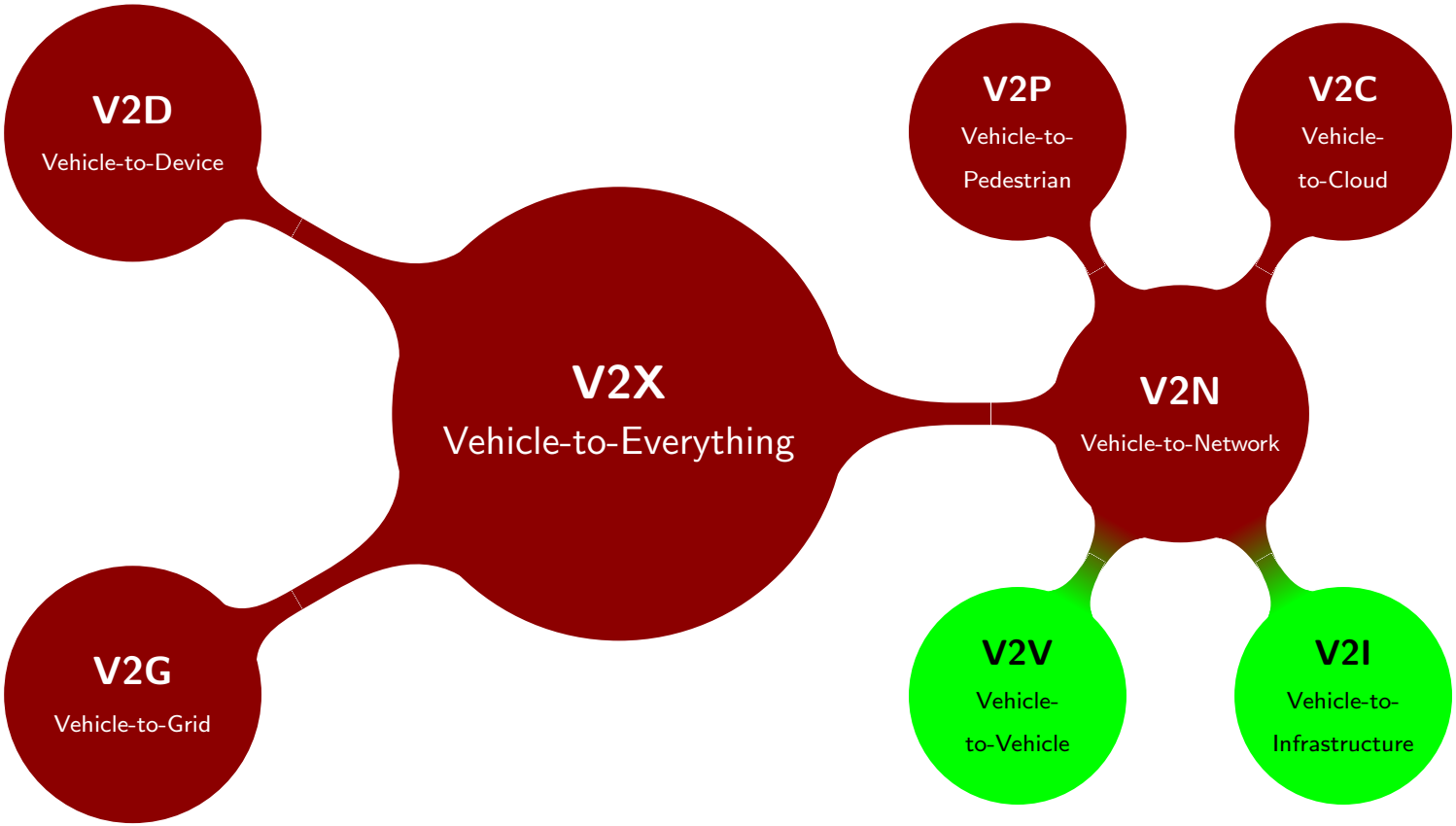

Figure 1: A breakdown of V2X.

Message Types in V2X

1. **Cooperative Awareness Messages** (CAMs)[1] and **Basic Safety Messages** (BSMs)[2].
   1. Exchanged between vehicles to create awareness and support cooperative performance of vehicles in the road network.
   2. Includes status information such as time, position, speed, active systems, vehicle dimensions, etc.
   3. Broadcasted unencrypted in 5.9 GHz channel (ETSI ITS-G5).
   4. **Huge privacy concerns and threats!**

[1] European Telecommunications Standards Institute. "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service". In: ETSI EN 302 637-2 V1.4.1 (2019). URL: https://www.etsi.org/deliver/etsi_en/302600_302699/30263702/01.04.01_60/en_30263702v010401p.pdf.

[2] *J2735_202309: V2X Communications Message Set Dictionary - SAE International*. URL: https://www.sae.org/standards/content/j2735_202309/ (visited on 04/15/2024).

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2. Other types of messages
   1. **Signal Phase and Timing** (SPaT)
   2. **Roadside Infrastructure Information** (MAP)

[1] European Telecommunications Standards Institute, "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[2] *J2735_202309*.

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2. Unlimited privacy.
3. Better security guarantees (privacy, authenticity, confidentiality).

Pairings

Definition 1

Pairing[a] Let $\mathbb{G}_0 = \langle g_0 \rangle$, $\mathbb{G}_1 = \langle g_1 \rangle$, $\mathbb{G}_T$ be three cyclic groups of prime order q. A *pairing* is an efficiently computable function $e : \mathbb{G}_0 \times \mathbb{G}_1 \to \mathbb{G}_T$ satisfying the following properties:

1. *bilinear*: for all $u, u' \in \mathbb{G}_0$ and $v, v' \in \mathbb{G}_1$, we have

$$e\left(uu', v\right) = e\left(u, v\right) e\left(u', v\right) \tag{1}$$

$$e\left(u, vv'\right) = e\left(u, v\right) e\left(u, v'\right) \tag{2}$$

2. *non-degenerate*: $g_T := e\left(g_0, g_1\right)$ is a generator of $\mathbb{G}_T$.

[a] *A Graduate Course in Applied Cryptography*. URL: https://toc.cryptobook.us/ (visited on 04/30/2024).

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1. Here, $\mathbb{G}_0$ and $\mathbb{G}_1$ are called *source groups* and $\mathbb{G}_T$ is called the *target group*.
2. When $\mathbb{G}_0 = \mathbb{G}_1$, the pairing is said to be *symmetric*.

Anonymous Key Agreement

1. A key agreement protocol where two parties agree on a shared secret key, without being able to determine the other party.

[3] Aniket Kate, Greg Zaverucha, and Ian Goldberg. "Pairing-Based Onion Routing". In: *Privacy Enhancing Technologies*. Ed. by Nikita Borisov and Philippe Golle. Vol. 4776. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, pp. 95–112. ISBN: 978-3-540-75550-0. DOI: 10.1007/978-3-540-75551-7_7. URL: http://link.springer.com/10.1007/978-3-540-75551-7_7 (visited on 04/04/2024).

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4. Clients can now create **psuedonyms** or fake identities $id \rightarrow (\mathcal{H}(id))^r, \mathcal{H} : \mathcal{ID} \rightarrow \mathcal{G}, r \in \mathbb{Z}_q$.

[3] Kate, Zaverucha, and Goldberg, "Pairing-Based Onion Routing".

Attributes, Credentials, Anonymous Credentials

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[4] Jan Camenisch et al. *Zone Encryption with Anonymous Authentication for V2V Communication*. 2020. URL: https://eprint.iacr.org/2020/043 (visited on 02/04/2024). preprint.

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4. For V2X
   - Anonymous credentials issued to vehicles regularly.
   - We use DGSA (Digital Group Signatures with Attributes)[4], which gives us a **randomizable** group element as the credential $\sigma \rightarrow \sigma^r, r \in \mathbb{Z}_q$.

[4] Camenisch et al., *Zone Encryption with Anonymous Authentication for V2V Communication*.

Proposed Message Flow Diagram

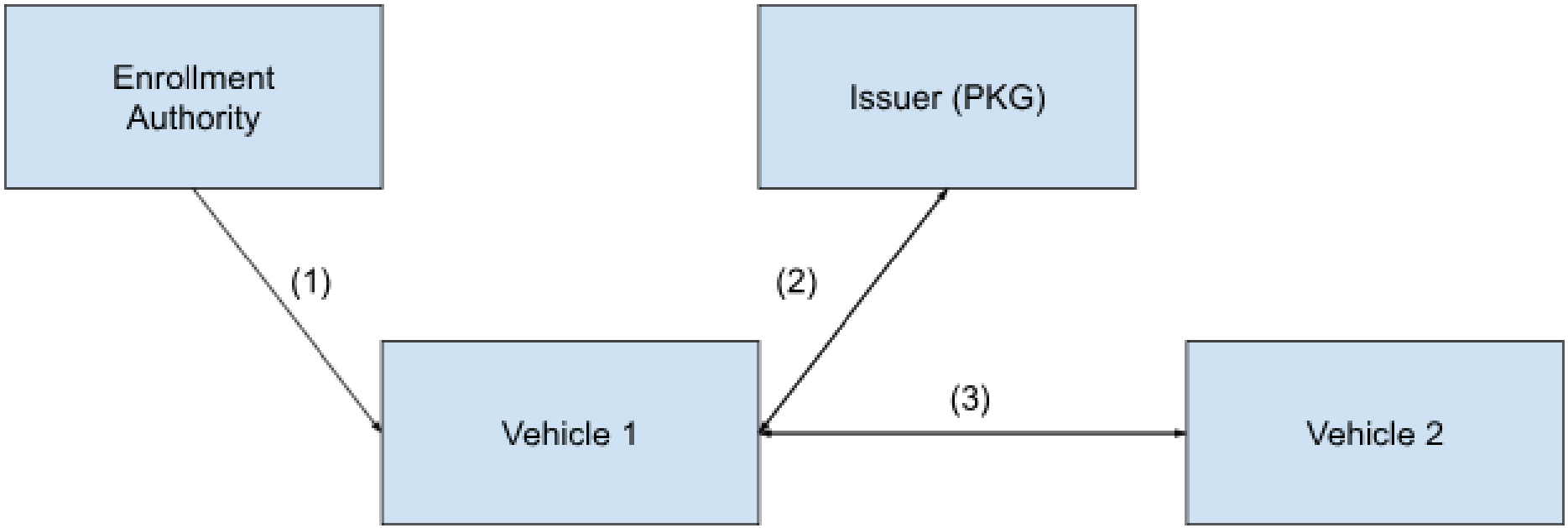

Figure 2: Message flow of the proposed scheme.

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3. Vehicles exchange DGSA-signed randomized psuedonyms to generate shared key for futher communicaton.
   - Used in verifying legitimacy of the other party.

Analysis

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   - Fully anonymous communication, unlimited privacy between communicating parties.
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   - Useful for sending extremely sensitive data.
   - Malicious vehicles can be revoked.
2. **Disadvantages**
   - Lots of pairing computations, for DGSA and for anonymous key agreement. Incurs computational overheads.
   - Works for single-hop connections only.
   - May not be scalable to communicating with many vehicles simultaneously in terms of storage overhead.

Future Work

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3. A new workflow for encryption using zones and zone managers.