

论文推荐 | 关于 6G 无线通信时延问题的新观点

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原文题目: [A Perspective on Time Toward Wireless 6G](#)

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随着 5G 技术的出现, 时延的概念在无线连接中扮演着重要的角色, 成为实时通信的代理术语。

随着无线系统朝着 6G 的方向发展, 将数字技术融入物理现实的雄心将得到提升。除了实时需求更加严格外, 这种沉浸感还将把时间 (time), 同时性 (simultaneity)、存在性 (presence) 和因果关系 (causality) 的概念提高到一个新的复杂程度。越来越多的研究指出, 时延 (latency) 不足以将所有实时需求参数化。值得注意的是, 这样的一个备受关注的需求是通过信息年龄 (AoI, Age of Information) 及其派生定义的信息新鲜度 (information freshness)。一般来说, 从通信网络设计的传统黑箱方法中得出的指标不能代表新的分布式范例, 例如感知、学习或分布式共识。

该文的目的是研究无线通信系统和网络中定时的一般概念, 及其与发送方和接收方有效信息生成、处理、传输和重建的关系。

该文建立了无线通信系统中定时要求的一般统计框架, 该框架包含延迟和 AoI。该框架是通过将计时组件与两个基本统计操作 (决策和估计) 相关联来实现的。首先使用该框架展示了现有无线通信定时工作的代表性示例。接下来, 展示了该框架如何与日益复杂的不同通信模型一起使用, 从基本的 Shannon 单向通信模型开始, 到共识、分布式学习和推理的通信模型。总之, 本文通过系统地处理无线通信中的各种定时度量, 填补了文献中的一个重要空白, 并为下一代实时系统的设计和优化奠定了基础。

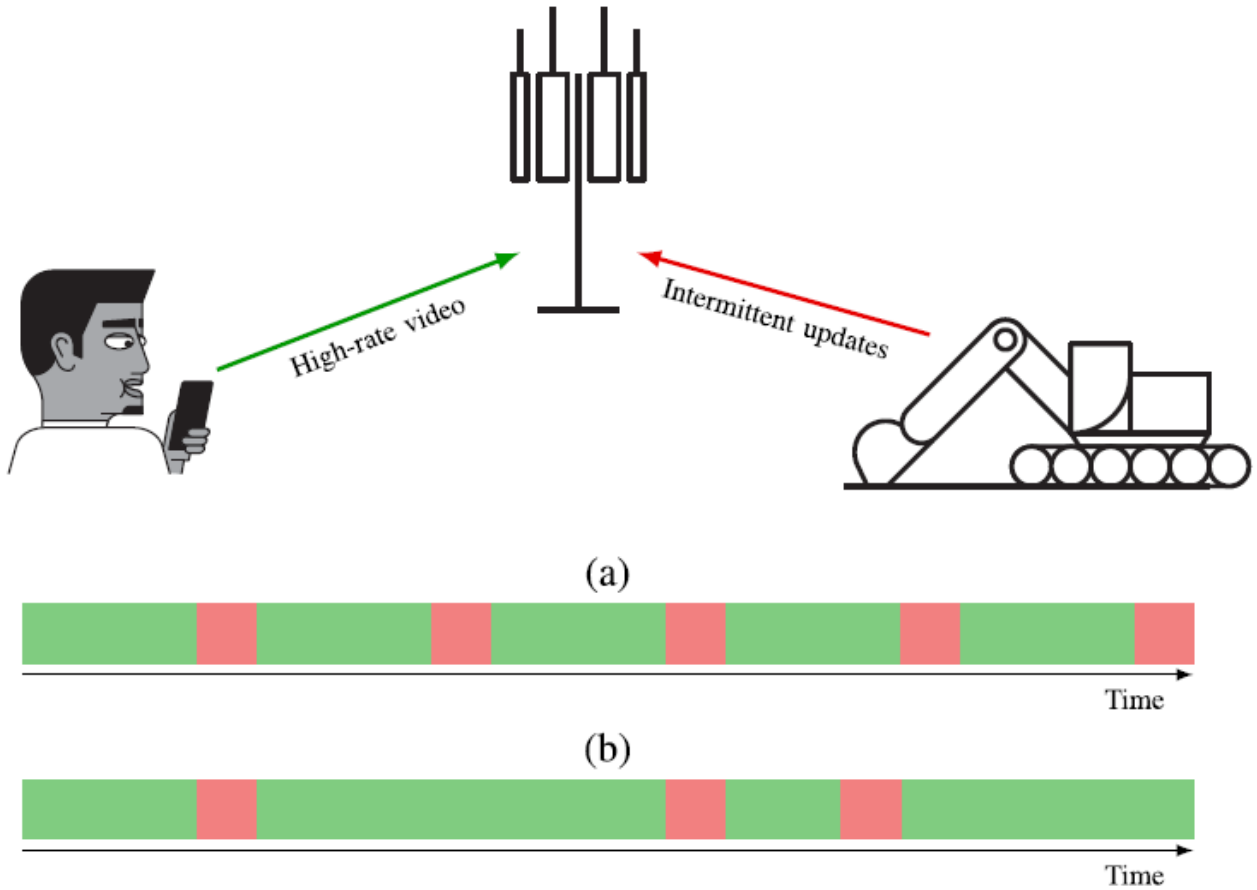


Fig. 1. Simple scenario in which two users of different types transmit in the uplink to a common BS. One is a high rate user, and the other user sends intermittent critical updates. (a) Scheme with low-latency reservations for the intermittent user. (b) Scheme with pull-based updates from the intermittent user.

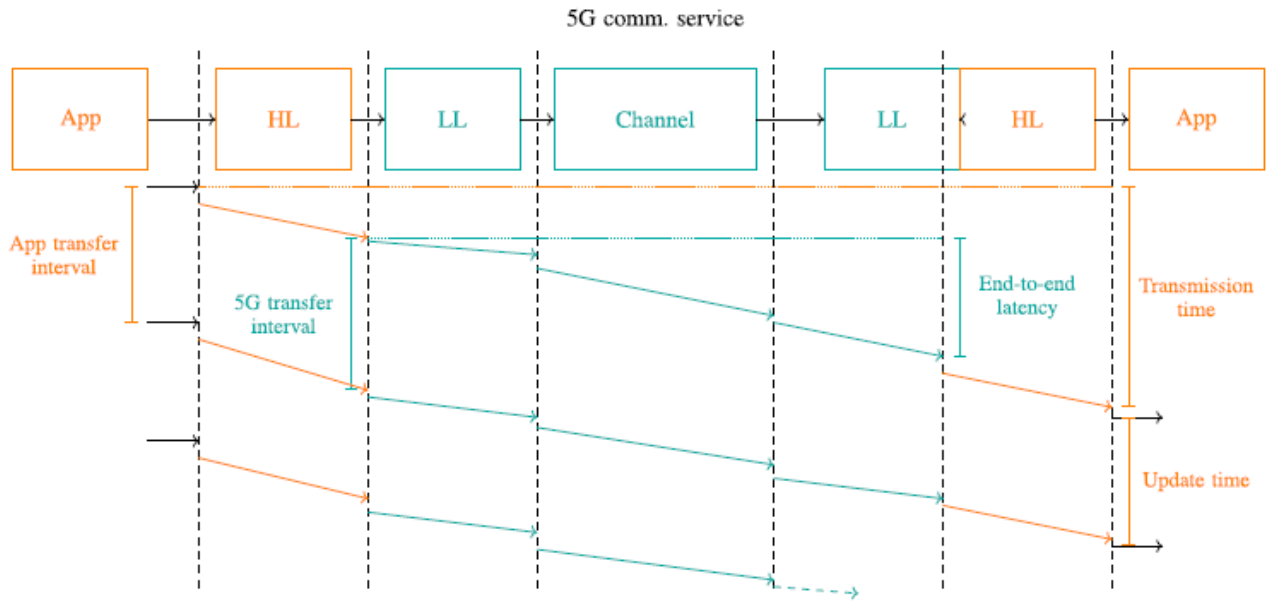


Fig. 2. General timing model from 3GPP [16].

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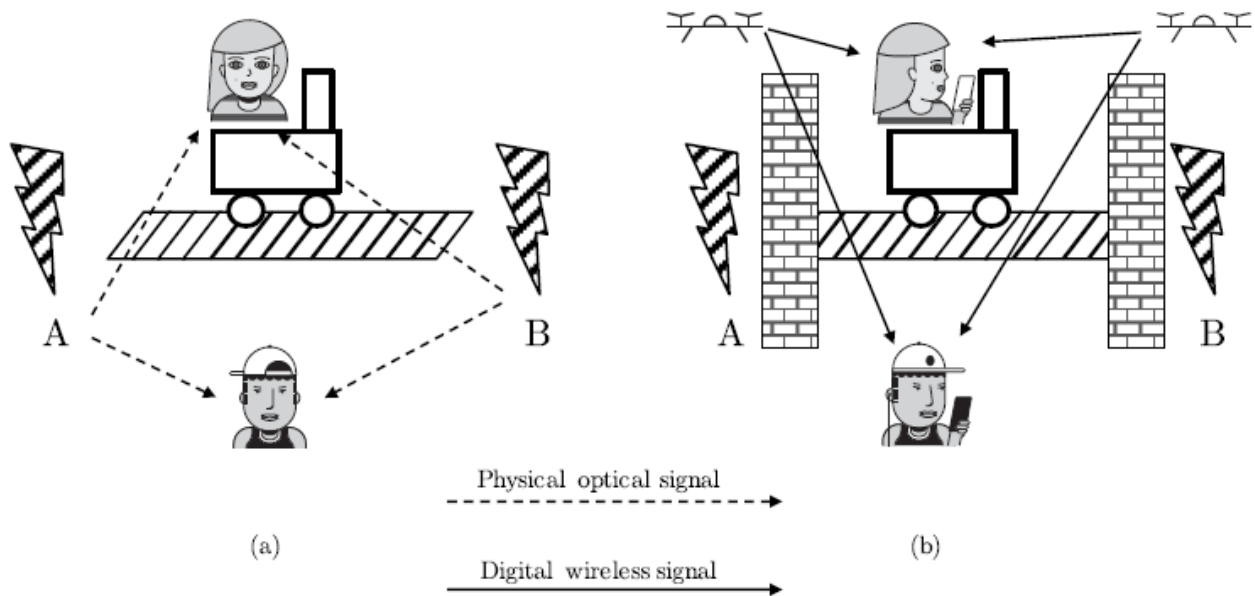


Fig. 3. Relativity of simultaneity. (a) Communication through a propagation of the physical optical signals. (b) Communication through a wireless digital system.

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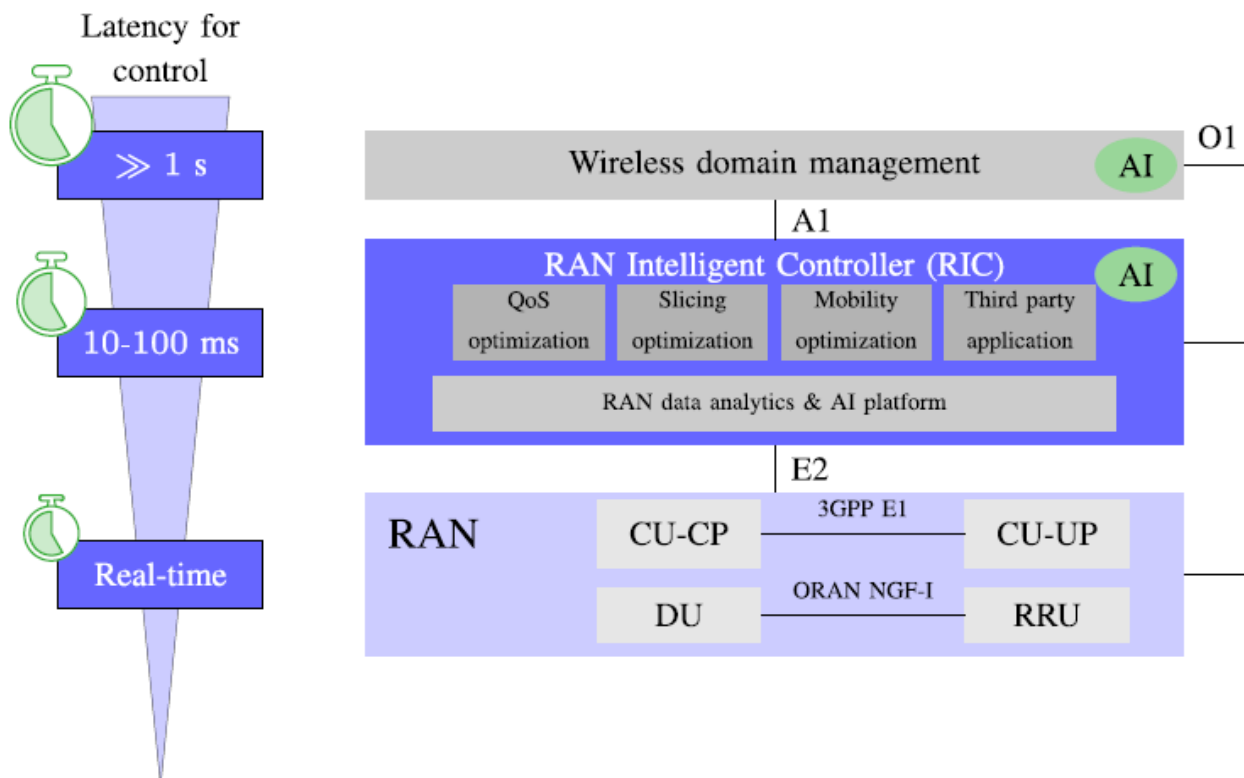


Fig. 4. Timing scales of the RAN intelligent controller in O-RAN [19].

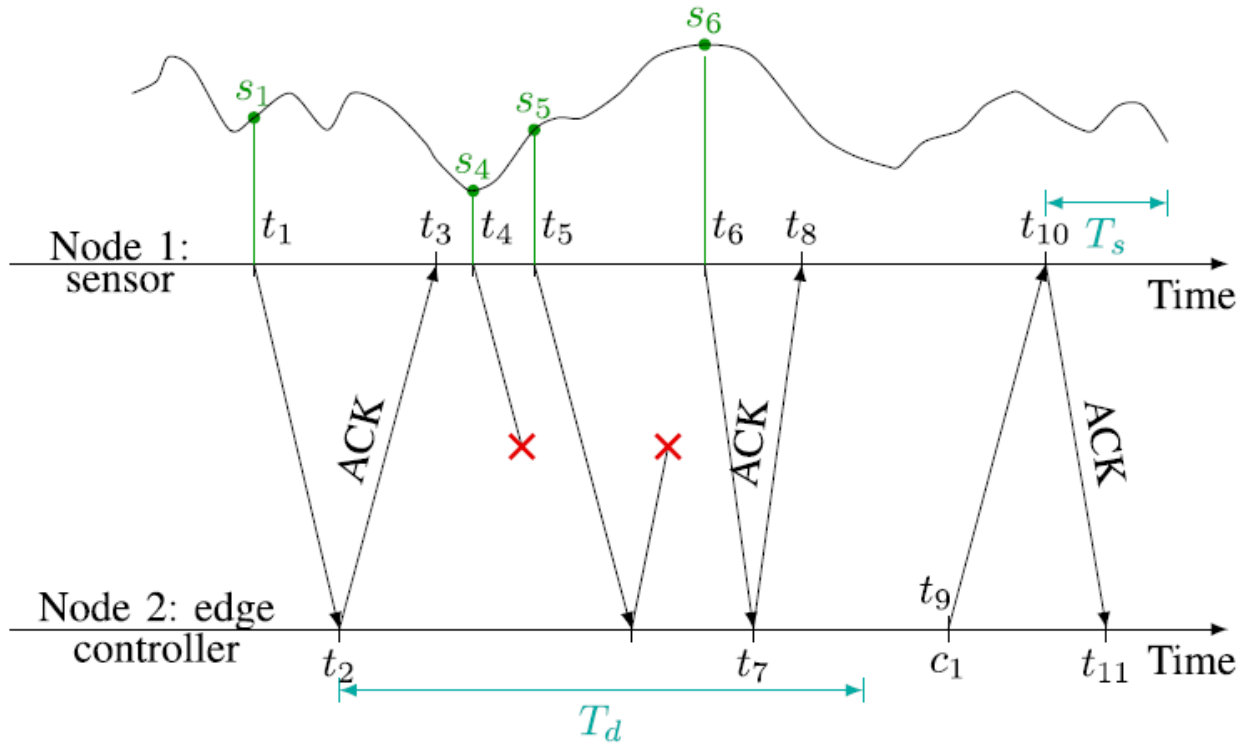


Fig. 5. Illustration of the timing references for a link between a sensor (Node 1) and edge controller (Node 2).

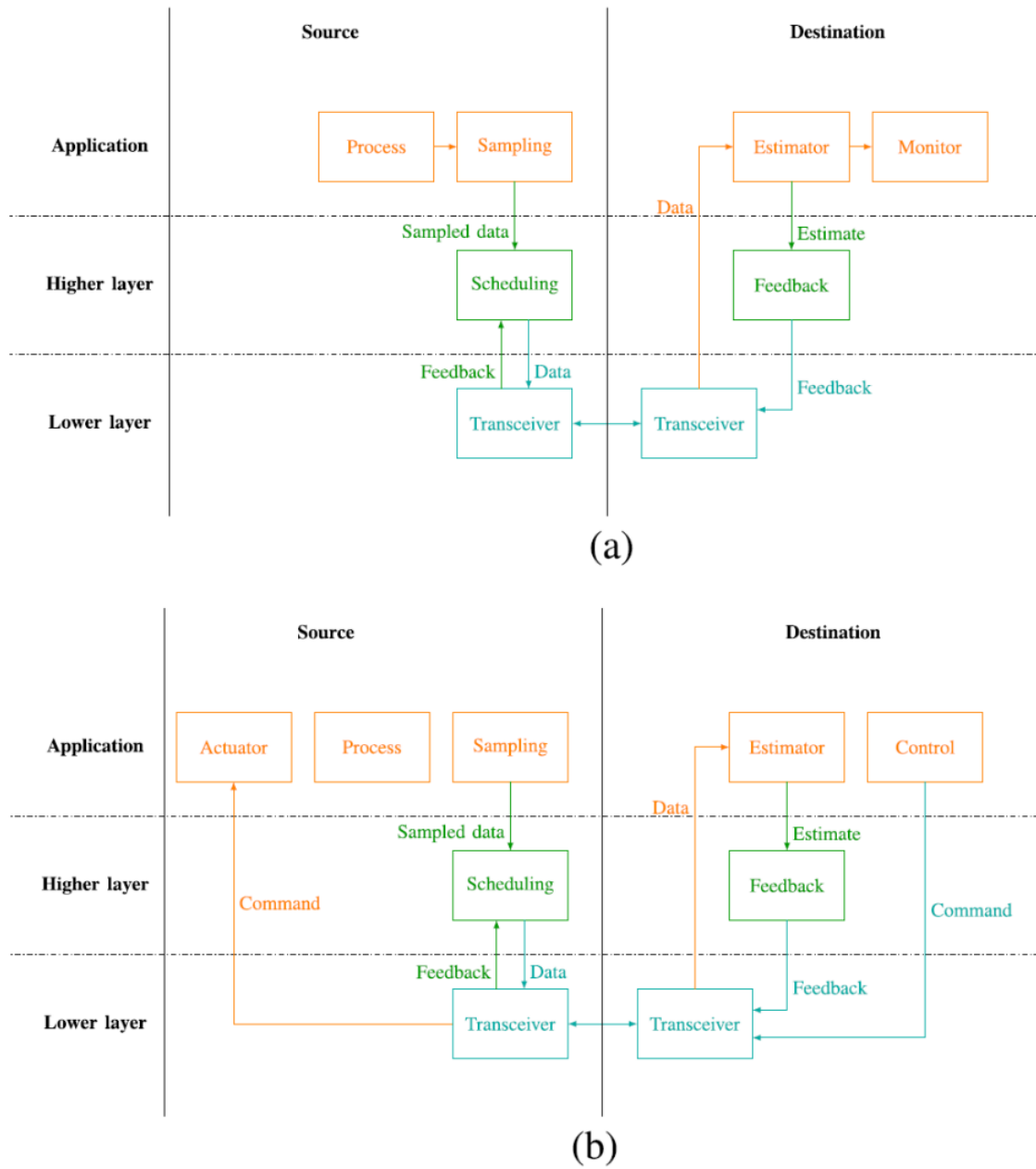


Fig. 6. Transmission model in an AoI (or beyond AoI) optimization scheme.
(a) Open-loop operation. (b) Closed-loop operation.

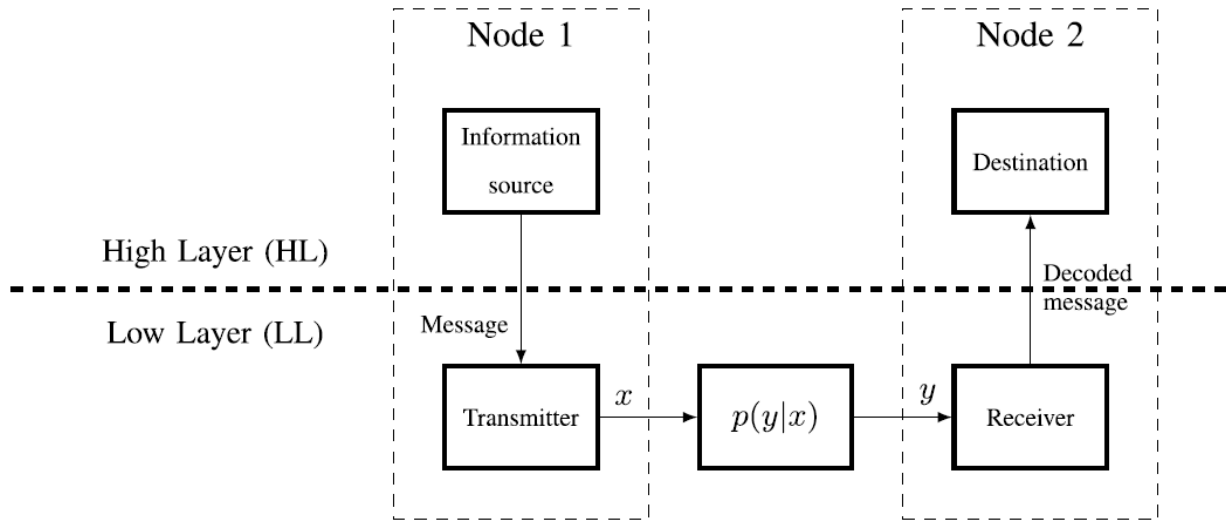


Fig. 7. Shannon's communication model annotated by layering.

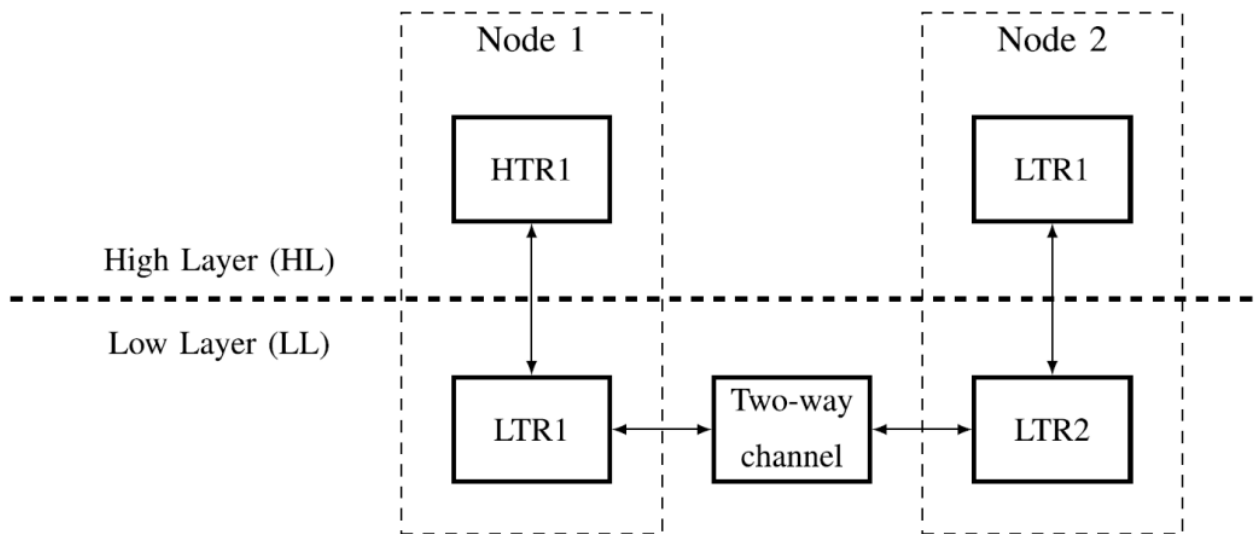


Fig. 8. Two-way communication model with two layers. HTR_i is the HL transceiver at node i ; LTR_j is the LL transceiver at node j .

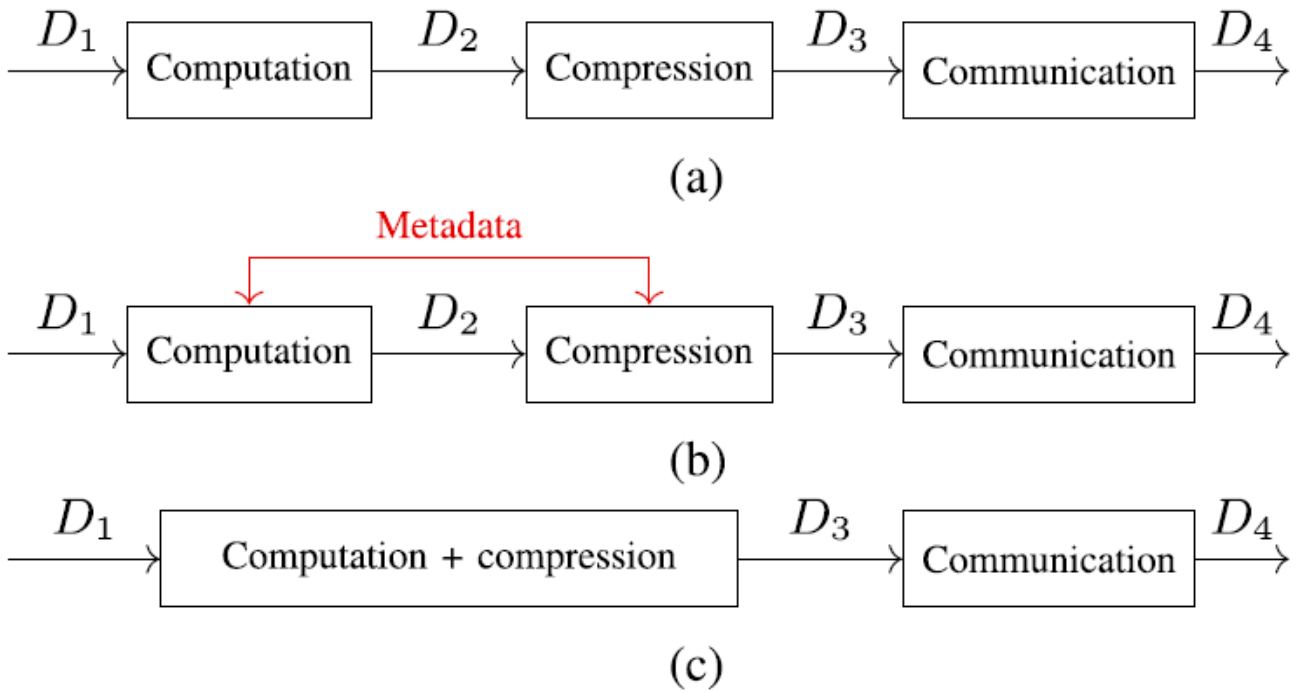


Fig. 9. Example of information processing through a cascade of modules. (a) Processing time of each module depends only on the data. (b) Processing times of computation and compression are coupled through control metadata. (c) Computation and compression are combined in a single module, and their processing times are inseparable.

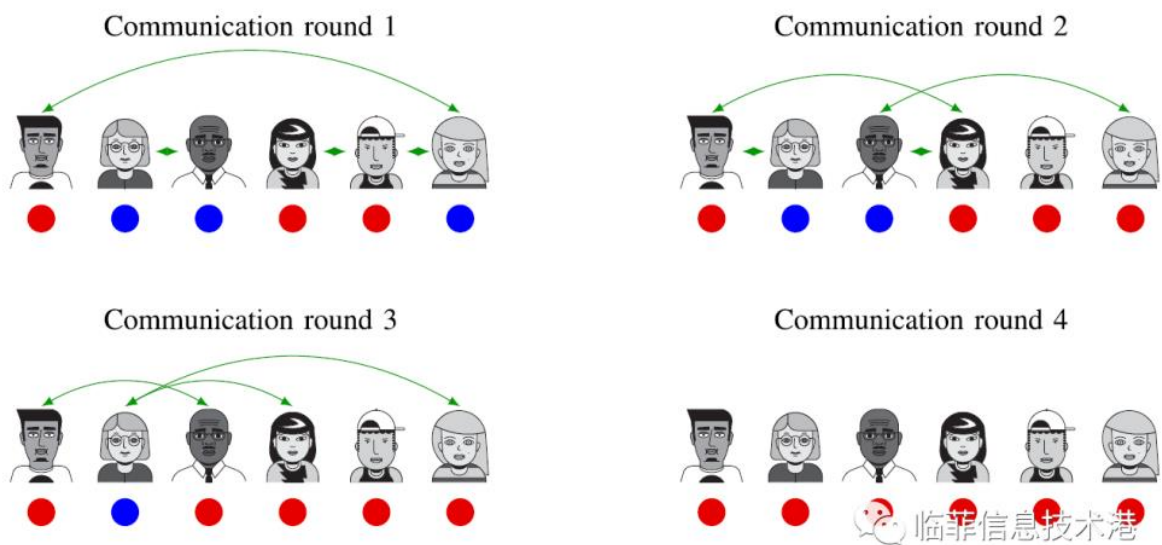


Fig. 10. Simple example of a distributed consensus.

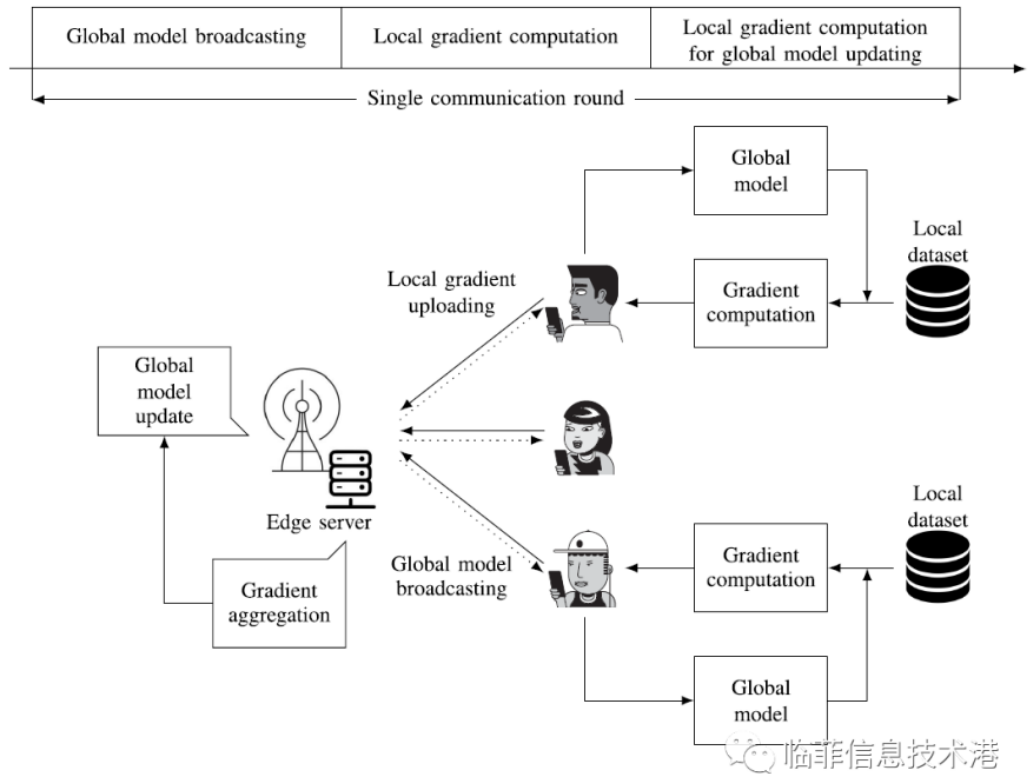


Fig. 11. Federated learning system and its operations.

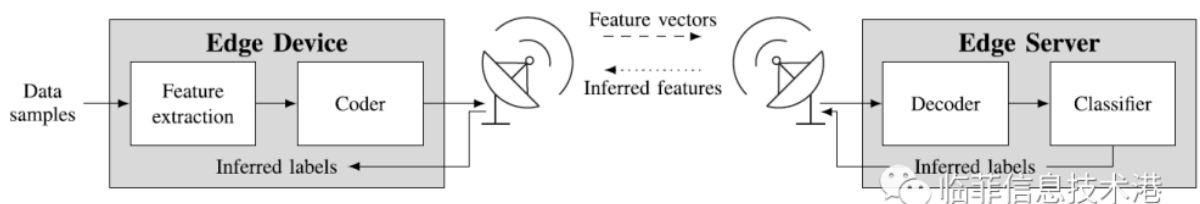


Fig. 12. Edge inference system and its operations.

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