Interview: Tad Matsumoto, Professor, Japan Advanced Institute of Science and Technology, Japan, and an appointed part-time professor at Center for Wireless Communications, University of Oulu, Finland

[IC1004]: Coding is an "old" subject, going back to the Shannon time. However, over all these years, it seems the scientific community and the specialists have been very active and have very much renewed the domain at regular intervals. Up to what extent do you think existing wireless networks could do without these efforts? (e.g., are turbo codes, LDPC, that much vital?)

[Tad Matsumoto]: In the systems where a 0.1 dB point-to-point signal-to-noise power ratio (SNR) improvement yields millions of dollars such as, for example, deep space communications, limit-achieving code design may still be a core issue of research. However, especially, in mobile wireless communications research communities, including COST IC 1004, is seeking for a 0.1 dB reduction in required point-to-point SNR meaningful? Obviously **no**! Instead, it is obviously much more meaningful to seek for the techniques that can achieve energy- and spectrum-efficiencies close to the network level limit than the (point-to-point) link level limit. This does not mean that the use of the powerful codes such as turbo and LDPC codes is meaningless; we could, of course, use such codes, but when we see the issues from the network design perspective, it is not necessarily to use capacity-achieving powerful component codes for signal transmission over the point-to-point links in the network. The most crucial point which we should recognize is that the information sequences received at the destination via multiple parallel routes are correlated, even though they may contain error(s), because they are all transmitted from the same source; if we can exploit the correlation knowledge at the destination in the decoding process, still there is a possibility that we can retrieve the information transmitted from the source.

[IC1004]: Can you tell us a bit about the philosophy of the RESCUE project in which you are involved and that targets a better resilience of wireless networks, of particular importance for disaster situations?

[Tad Matsumoto]: The EU FP7 Project RESCUE stands for "Links-on-the-fly Technology for Robust, Efficient and Smart Communication in Unpredictable Environments. The project has targets: creating new broadband wireless communication network concepts (1) that perform *beyond-point-to-point Shannon-limit* and *close to the network-level limits* of energy and spectrum efficiencies, and (2) that enhance robustness and flexibility against unpredictable network topology changes. The RESCUE project is motivated by the Japanese experience of huge disaster due to the massive earthquake on March 11, 2011, followed by a series of unprecedented level of Tsunami that caused the Fukushima nuclear power plant devastation. The necessity for creating robust, flexible, and "always-connectable" networks has been recognized since then. Such networks include not only public communications systems but also sensor networks having a lot of sensing nodes located in a huge pile of wrecks in the devastated plant, and vehicle-to-vehicle, machine-to-machine, and device-to-device communications systems.

[IC1004]: In this project, you explain that "the network is the code". This seems somewhat obscure. Can you explain in one or two sentences what this means?

[Tad Matsumoto]: The decode-and-forward (DF) protocol has presently been considered for years as one of the most practical cooperative communications techniques, because of its simplicity; it does not require the channel state information of the previous hop section to be forwarded to the following sections. Conventional DF systems stop forwarding the information sequence, if the decoder of a forwarding nodes detects error(s). However, as noted above, the information sequences received via the multiple routes are, if they are forwarded to the destination, highly correlated, although they may contain error(s). The RESCUE project refers the technique to as "lossy-forwarding". With the lossy-forwarding technique, it is quite likely that we can preserve multiple communication routes in the network having super-densely populated nodes, hence it is not necessary to use capacity-achieving powerful error correcting code for signal transmission between the nodes. In other words, the network utilizing lossy-forwarding technique is, as a whole, an error correcting code where the redundant part is located not only in the time domain but also over the network. From the viewpoint of Network Information Theory, designing a network with lossy-forwarding can be categorized as a problem of "source coding with helper(s)". With the concept of lossy-forwarding, the network can attain the robustness and flexibility against the network topology change, where the knowledge of the correlation between the received erroneous sequences can be estimated only by the destination.

[IC1004]: is there any relation with "network coding"? This relatively recent way to process data between a source and a sink involving relays intends to be more efficient than for independent P2P routes, is that so different from the RESCUE approach?

[Tad Matsumoto]: In principle, the lossy-forwarding concept is different from network coding techniques, but they can easily be combined. This means that the lossy-forwarding concept can be applied not only to the network with parallel routes; there are a lot of possibilities to apply the concept, with the aim of achieving network-level energy- and spectrum efficiency limits. For example, assume that there are multiple sources and one relay nodes. The relay node performs network coding even though the relay detects error(s) in the information sequence(s) from the source(s). Design of such network can be viewed as a problem of Slepian-Wolf source coding with helper(s).

[IC1004]: it seems complicated to design codes that operate at PHY, MAC and even at routing levels together. Don't you think the practical implementation of such codes in practical networks will be hard to achieve? How far could they come into existing (3G, 4G) or future (5G and beyond) networks?

[Tad Matsumoto]: Well, this is a difficult question to answer, because employment of new technologies requires agreement of the industry, which takes quite long a time. RESCUE is planning to conduct a demonstration at the final stage of the project.

[IC1004]: Thank you!

Tad Matsumoto is currently serving as a professor at Japan Advanced Institute of Science and Technology (JAIST), Japan and also serving as an appointed part-time professor at University of Oulu, Finland. He received his Ph.D. degree from Keio University, Yokohama, Japan, in 1991, in electrical engineering. He worked at NTT DoCoMo until 2012. His research interest covers turbo equalization, iterative detection, code design for distributed systems, distributed coding. Currently, he is working on the establishment of unified techniques for the design and analysis of lossy-forwarding wireless cooperative networks based on the theorem of multiuser source coding with a helper in Network Information Theory.