DISTRIBUTED SDN IN AN INTELLIGENT EDGE FOR THE FUTURE 6G NETWORK

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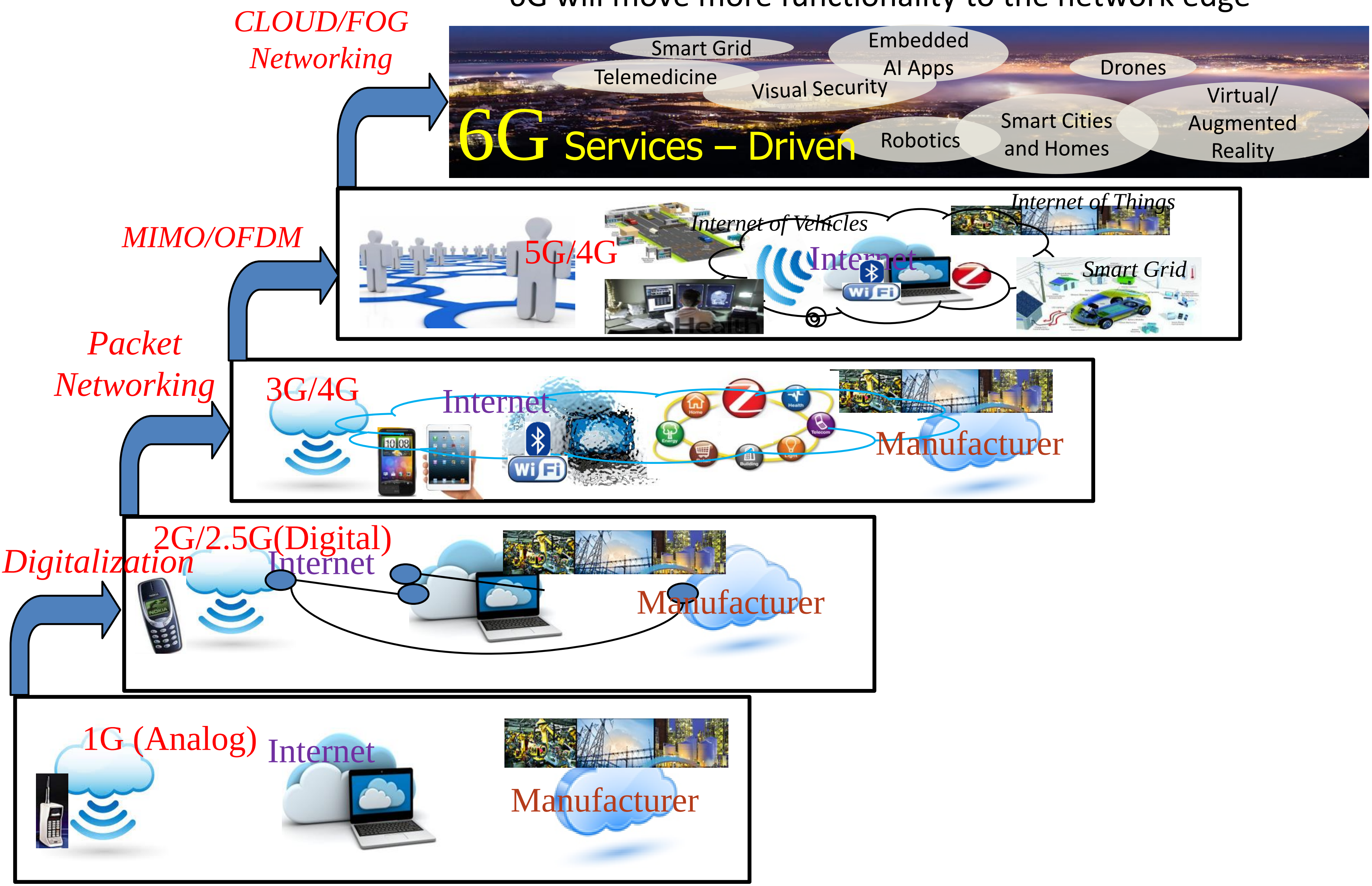
This brief high-level presentation explains why and how we might implement software defined network (SDN) capabilities in the intelligent (AI-assisted) edge of the future high performance 6G network.

This highly adaptive distributed SDN is a departure from present-day concepts of a centralized and only slowly adaptive SDN.

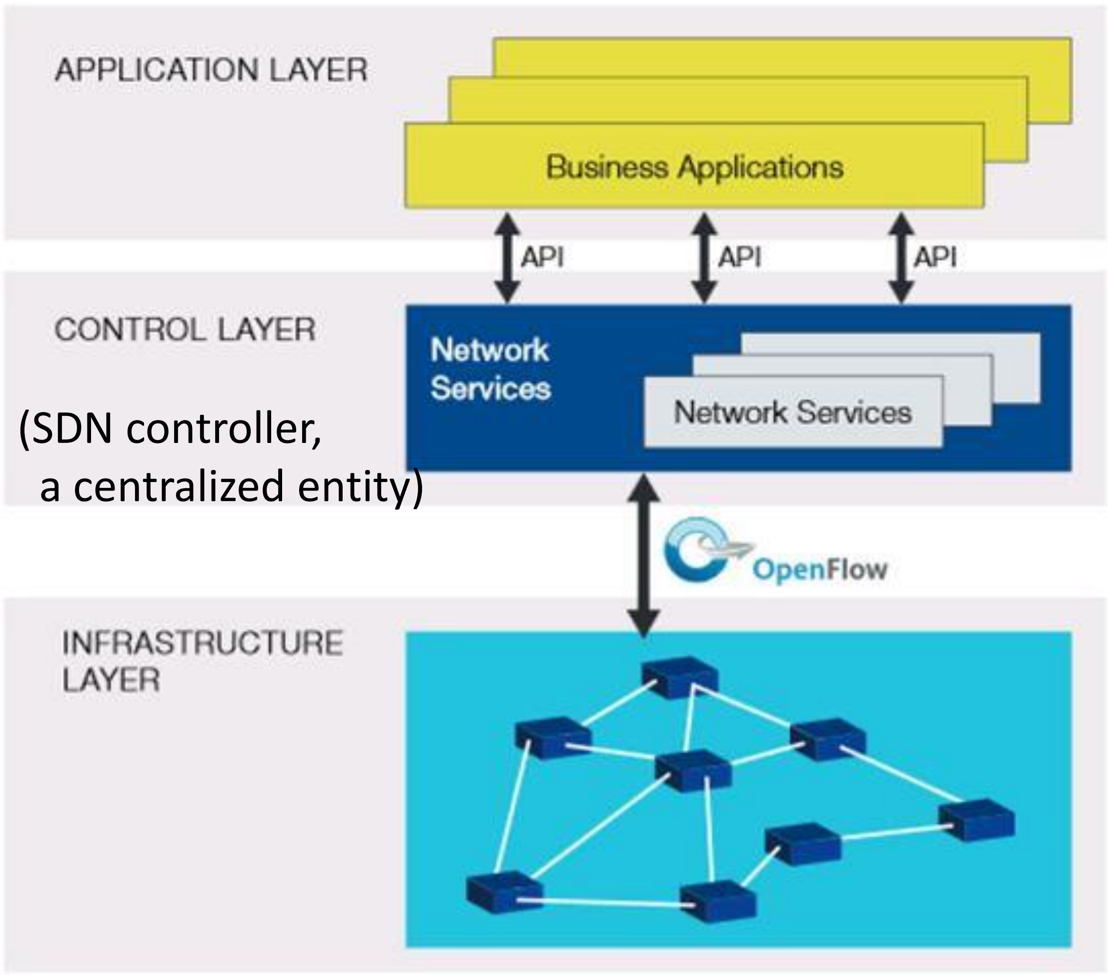
6G networks will stress very high data rates, exceptionally low latency, and extensive use of network edge resources.

Wireless Evolution: Technologies, Services and Business Models

6G will move more functionality to the network edge



Today's centralized SDN



Source: "OpenFlow enabled SDN and Network Functions Virtualization", ONF Solution Brief, Feb. 17, 2014, available at https://opennetworking.org/wp-content/uploads/2013/05/sb-sdn-nvf-solution.pdf

The centralized control structure has limitations:

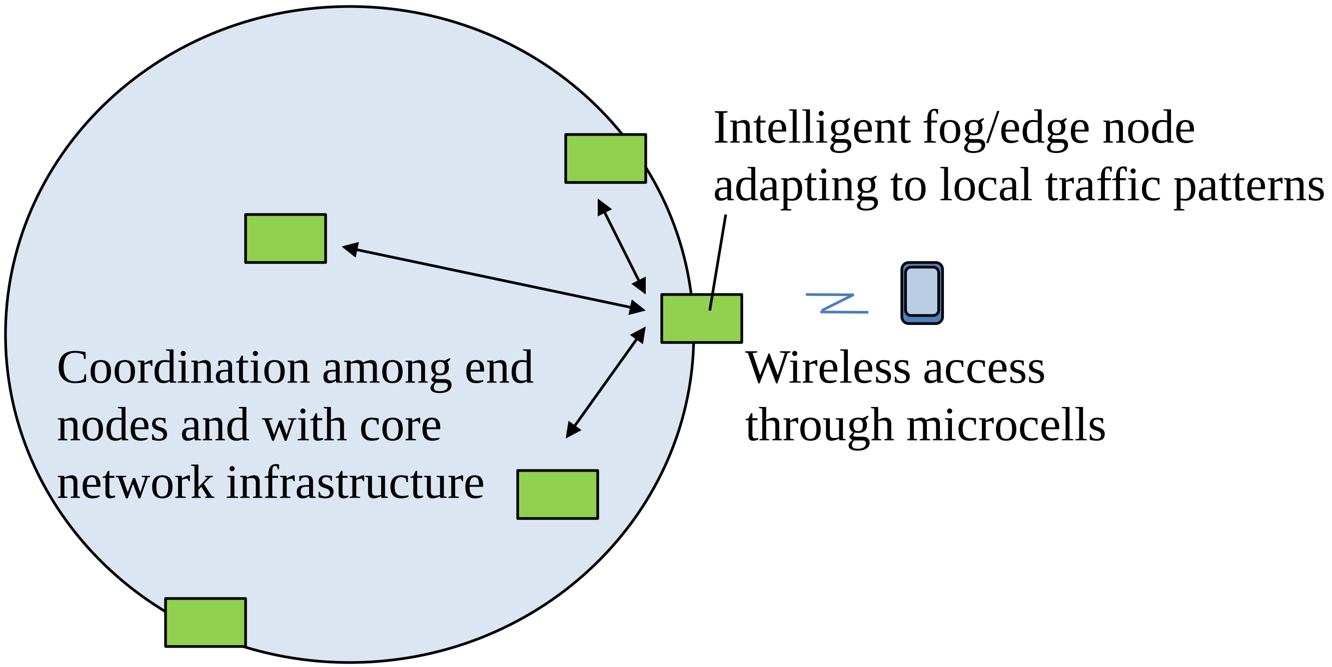
-Delay in adjusting resource allocations in response to rapid local changes in the composition of traffic.

-Vulnerability to network-wide damage if the centralized SDN controller develops faults or is hacked.

-Lack of flexibility to meet widely varying traffic patterns in different parts of the network.

This limits its utility in services-driven 6G wireless networks designed for high data rates, low latency, and providing an attractive platform for entrepreneurial development of new network and application capabilities.

Our proposal for 6G networks is an AI-powered fog/edge platform with storage, communications, control (SDN) and processing resources.

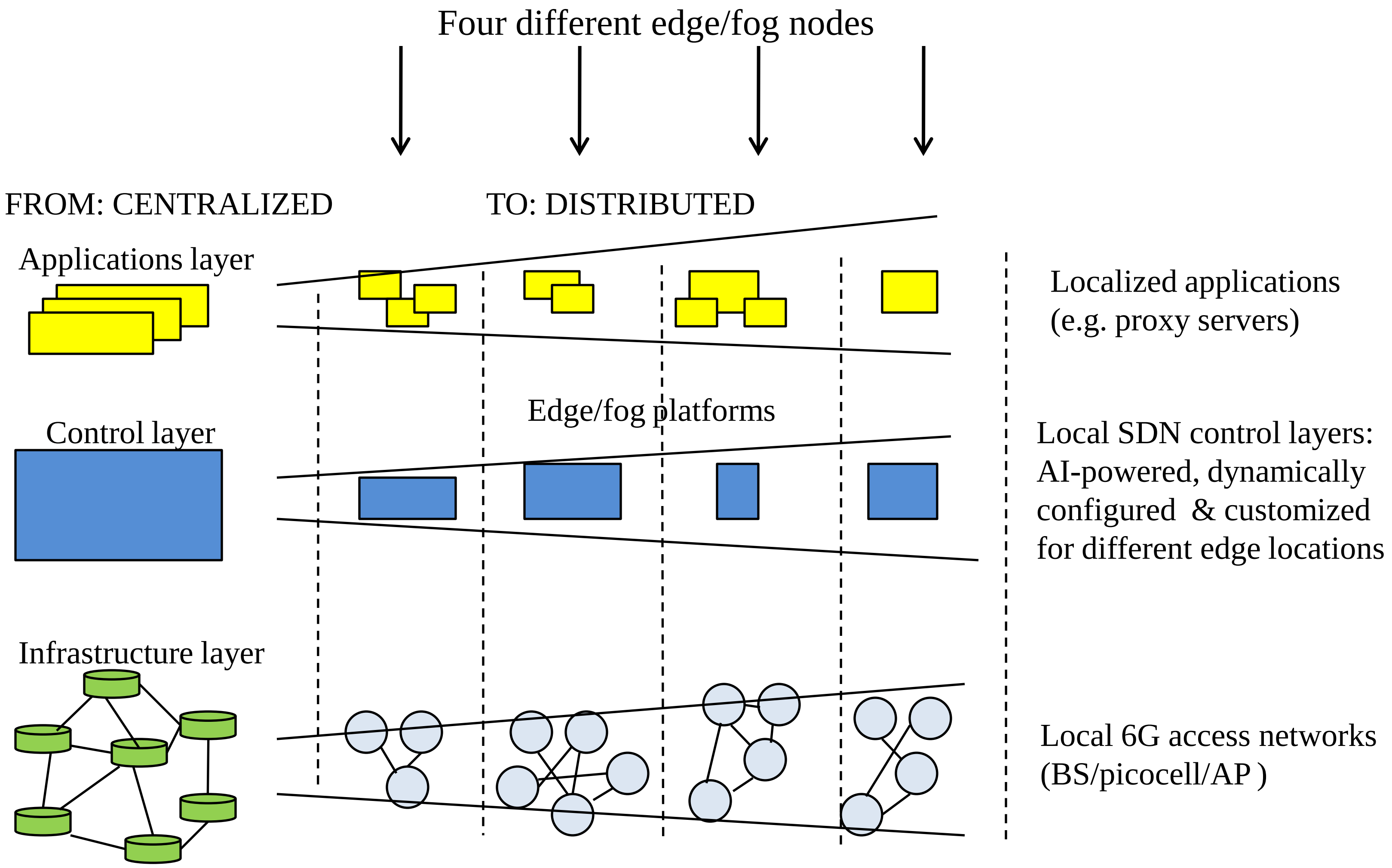


Similar ideas have been developing in the communications R&D community ...

“Fog computing, ... intended for alleviating .. network burdens at the cloud and core network, [moves] resource-intensive functionalities such as computation, communication, storage, and analytics closer to end users ....making use of machine learning to detect user behaviors and perform adaptive low-latency ... scheduling [and] task offloading.”

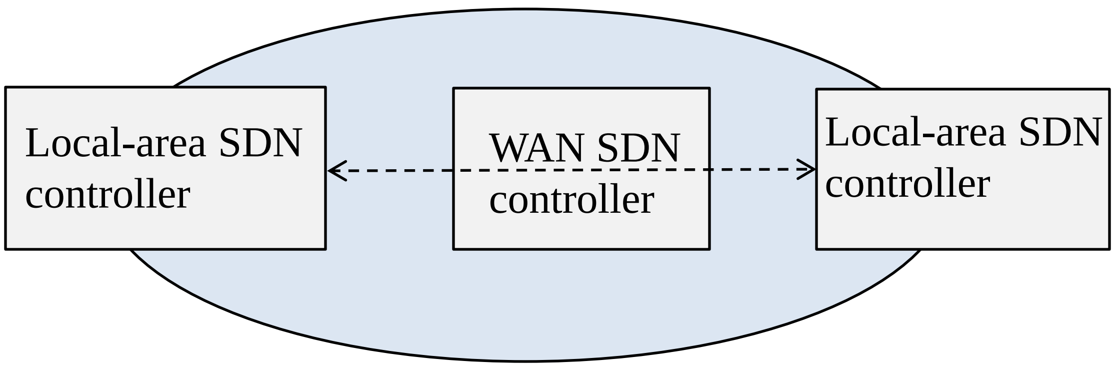
Quang Duy La et.al., “Enabling intelligence in fog computing to achieve energy and latency reduction”, Digital Commun. & Network, vol. 5 issue 1, Feb. 2019 https://www.sciencedirect.com/science/article/pii/S2352864818301081

The transition can be represented this way

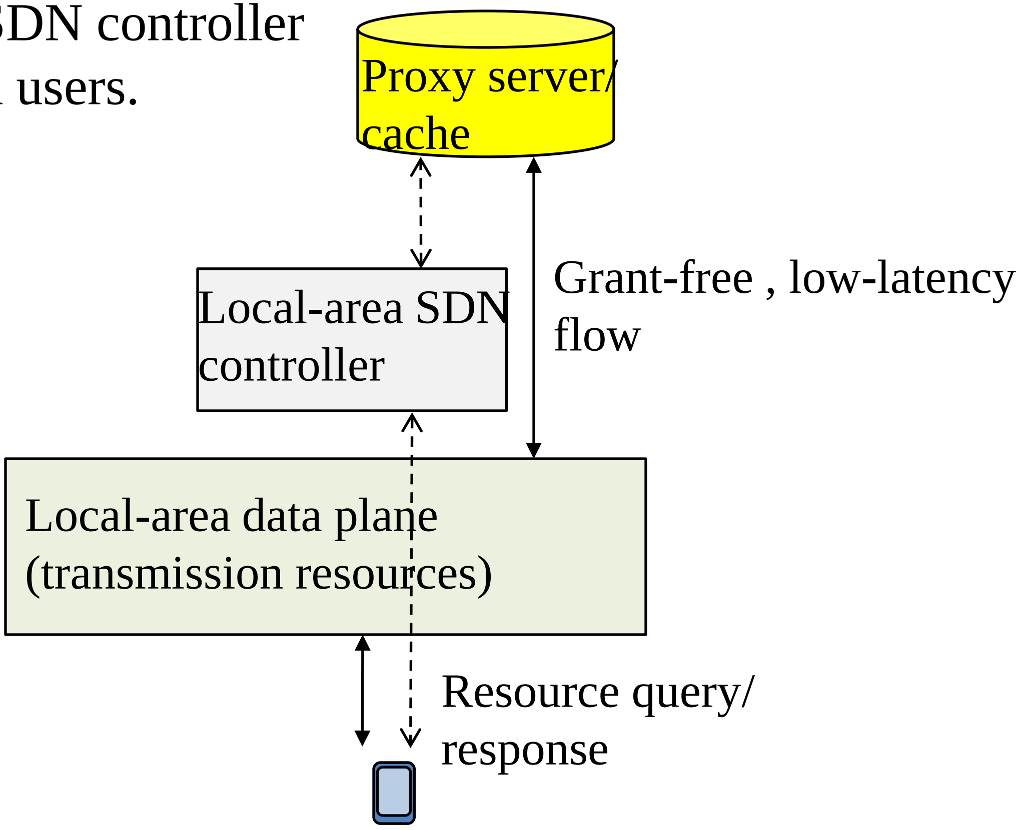


Autonomous local SDN controllers allocate resources and define local network topologies, functionalities and services.

For distant flows, the local SDN controllers coordinate with each other for efficient wide-area services. A local SDN controller makes an information flow request to, and receives capacity grants from, the core network (WAN) control layer and from the distant local control layer.



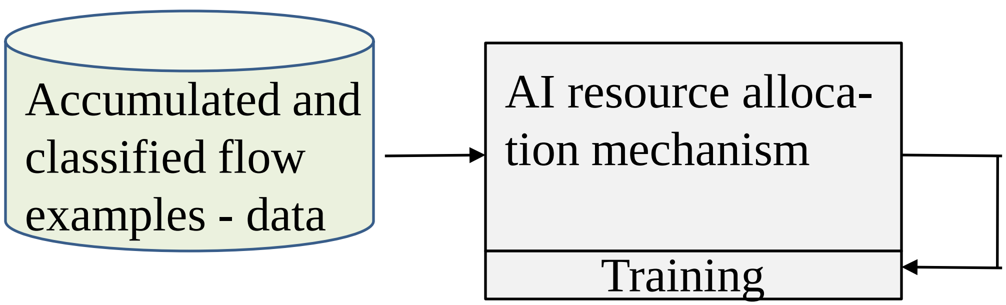
For more local flows, such as retrievals from a nearby proxy server, the local resource entities, such as the local data plane and local servers in the fog, rapidly provide resource availability information to the local SDN controller without the request/grant overhead and latency required for wide-area flows. The local SDN controller provides this information to end users.



How is this distributed SDN resource-allocating controller trained and subsequently made adaptive to local conditions?

-Both factory training and post-deployment adaptation may advantageously exploit AI machine learning.

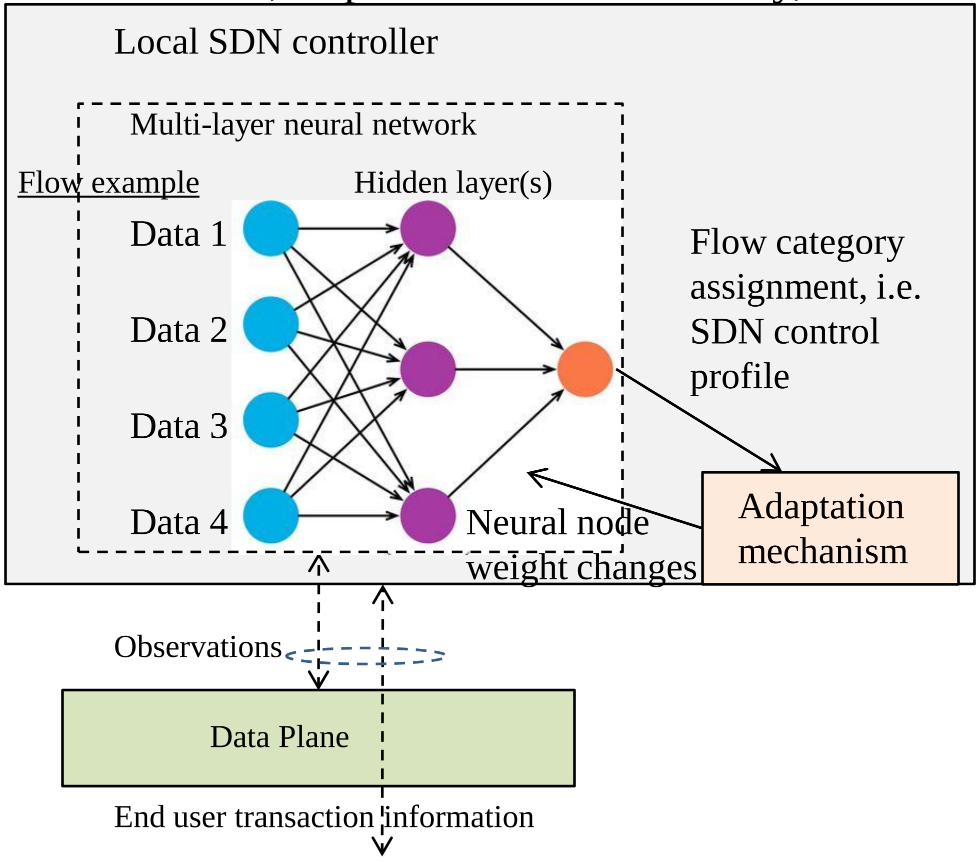
-Initial settings are likely to be based on AI machine learning from large databases of traffic observations.



-Subsequent adaptation of the controller to local conditions enables the controller to create resource pools for different traffic classes, and offer those resources to end users with minimum querying of the resource entities.

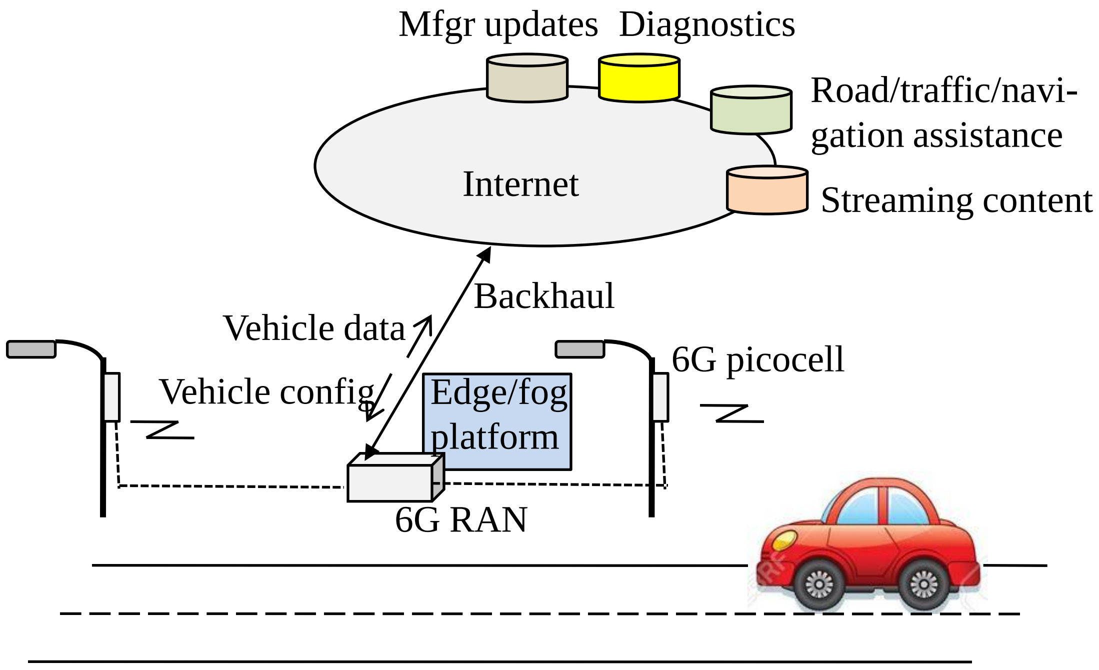
Example: Neural network adaptation of the SDN controller to local conditions

- Data from a flow in a communications/computing session serve as a training example.
- The hidden layer optimizes for relevant features, such as rate, latency constraints, security requirements and storage/processing requirements.
- The output layer makes a decision for one of a set of SDN control profiles regulating the assignment of resources to different classes which may be defined by features such as relative use of fog-based local resources, importance of low latency, and average session transmission rate.
- An error function drives adaptation of the neural node weights.



An application scenario: Vehicular telematic services

-Key vehicular software updates, maps, and even entertainment content will be cached locally in the edge/fog platform rather than retrieved from distant databases.
-Accommodation of dynamically changing clients and requirements along streets and highways.



Conclusions and further work

-Distributing control and content caching to the network edge supports a fast-adapting, service-sensitive allocation of resources to information flows.

-SDN provides a proven architecture for the control functions if it is modified into a distributed infrastructure that can reduce latency and resource contention conflicts by better managing the local resources.

-Adaptation of this distributed SDN may be effectively implemented in multi-level neural networks.

-It remains for us to do simulations to confirm the effectiveness of the proposed design.

Thank you for your attention!