Static Evaluation of a Wheel-Topology for an SDN-based Network Usecase

Dimitrios Savvidis
Chair of Automation / Computer Science
University of Wuppertal
Wuppertal, Germany
savvidis@uni-wuppertal.de

Robert Roth
Chair of Automation / Computer Science
University of Wuppertal
Wuppertal, Germany
rroth@uni-wuppertal.de

Prof. Dr.-Ing. Dietmar Tutsch
Chair of Automation / Computer Science
University of Wuppertal
Wuppertal, Germany
tutsch@uni-wuppertal.de

***Abstract*—The increased occurrence of Software-Defined-Networking (SDN) not only improves the dynamics and maintenance of network architectures, but also opens up new use cases and application possibilities. Based on these observations, we propose a new network topology consisting of a star and a ring topology. This hybrid topology will be called *wheel topology* in this paper. We have considered the static characteristics of the *wheel topology* and compare them with known other topologies.**

***Index Terms*—SDN, topology, wheel**

I. Introduction

In an effort to follow the current trend of cloud applications and "smart systems", more and more everyday systems are equipped with some form of "intelligence". Usually this means that the existing hardware is extended with some kind of interconnectivity, i.e. a network interface, which is shaped by software throughout the hardware's lifecycle. This software may add new functionalities and correct errors. The software defines the functionalities of the used system. This concept is commonly called Software-Defined-Systems (SDS). One characteristic of the SDS concept is the Software-Defined-Networking (SDN), which allows to decouple network hardware from software: a central network controller, called Control Plane (CP), controls the network and replaces the hardware's existing software and firmware. The network hardware for transmitting the necessary data packets and executing the CP instructions is called Data Plane (DP) [1]. By decoupling the software from the network hardware, it is possible to dynamically adapt the network infrastructure and hardware in its functionality to the requirements. In this paper, we propose a network topology consisting of a star and a ring topology. This hybrid topology will be called *wheel topology* and can be seen in Fig. 1. We have considered the static characteristics of the *wheel topology* and compared them with known other topologies. Through the static analysis of the wheel topology, we establish the basics for the later use by SDN.

II. Introducing the Wheel-Topology

The idea of the wheel topology is based on ring topology and star topology (see in Fig. 2) merged together and has similarities with the STARNET topology. The STARNET topology was first introduced by Poggiolini and is an optical broadband LAN network that implements packet-network and WDM circuit interconnect [2]. Based on STARNET, there are several similar appearing topologies with different names, especially in the network-on-chip (NoC) field. Some similar topologies are the Octagon topology [3] or Spydergon topology [4], diagonal mesh topology [5], STAR-RING topology [6] and the Wheel-Rim topology [7]. Our wheel topology differs from the other ones by the fact that the nodes on the ring and the star are all switches. The actual nodes are connected to the external switches such as leaves. We call the number of switches N and the number of nodes M. The wheel topology has $N-1$ switches which form the ring and are connected bidirectionally to the left and right neighbouring switch. Additionally, there is one switch in the center, known as a *star switch*, which is connected bidirectionally to all the external switches. From now on the external switches will be called *satellite switches*. An individual number M of *nodes*, i.e. nodes or leaves, are connected bidirectionally to each satellite switch. The satellite switches and their nodes build a local star topology. By their structure the wheel topology has a diameter of $\varnothing = 4$ from node to node. The number of connections is called *degree* (number of ports) Pt. Pt is for a node 1 and for the satellite switches $3+M$. The degree Pt of the central switch is $N-1$. The number of connections that must be removed to interrupt the network is called *edge connectivity* K. For the satellite switches K is 3 and for the central switch it is $N-1$. For the nodes, K is 1. The bisection-

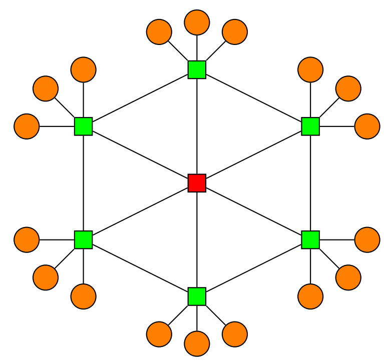

Fig. 1. wheel topology: consisting of seven switches and three nodes on each satellite switch

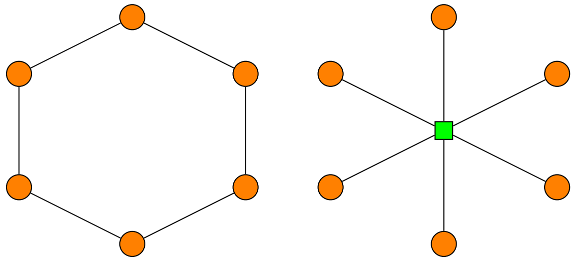

Fig. 2. ring and star topology

width B is $\lfloor \frac{N}{2} + 2 \rfloor$. The bisection-width is the minimum number of links to be removed to divide the network into two equal subnetworks. The connection complexity V_b is the total number of all unidirectional connections links in the network. For bidirectional links V_b must be multiplied by two:

$$V_b = 2(M + 2)(N - 1) \tag{1}$$

Because of the symmetry of the topology, the average path length of all possible sender-receiver pairs with M nodes and N switches are:

$$\bar{r} = \frac{2 \cdot (M - 1) + 3 \cdot 2M + 4 \cdot (N - 4)M}{(M \cdot (N - 1)) - 1} \tag{2}$$

For $M = 1$, see in Fig. 3, Equation (2) results in:

$$\bar{r} = \frac{4N - 10}{N - 2} \tag{3}$$

The derivation of the equation is now motivated by the example of Fig. 1 with $N = 7$ and $M = 3$. We select some node that we use as sender for the calculation for the average path length. Because of the symmetry from the topology, it is sufficient to consider only one node. Let's first look at the numerator of the Equation (2) and see how many different hops are possible. For a node connected to the same satellite switch, the number of hops is two. For $M = 3$, two paths of *length two* are necessary. This results in $2 \cdot (M - 1)$ in general. Path of *length three* are required for a node on a neighbouring satellite switch. In our example there are 6 of these nodes (in general: $2M$), which results in an added path length of $3 \cdot 2M$. The distance to all other remaining nodes is *length four*. To sum up, we must now consider the remaining satellite switches. In our example this is 3 switches. Because we do not have to consider the switch under investigation, the two neighbouring switches and the central switch, it follows that $(N - 4)$ switches remain that require paths of *length four* to their nodes, which results in $4 \cdot (N - 4)M$. We have now derived the numerator of the equation. Next we have to divide by the number of all connections. Since we have $N - 1$ switches that have nodes, we have to multiply this by the number of nodes M, which results in $M \cdot (N - 1)$. As we do not have to consider the node under investigation, we still have to subtract this node. The denominator is then accordingly $M \cdot (N - 1) - 1$. With the numerator and denominator that we have just derived, this leads to the average path length as derived in Equation (2). A comparison with the most important characteristics of other popular network topologies is shown in Table I.

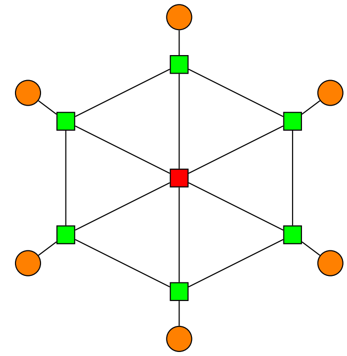

Fig. 3. wheel topology with $N = 7$ and $M = 1$

III. Wheel topology with SDN

The intention behind the wheel topology is to combine the advantages of the ring and star topology and to achieve an improvement in bandwidth, a reduction of latency and a higher level of robustness. In the typical network area, such an architecture would generate loops and lead to network collapses or network storms. Through the application of SDN and the related usage of SDN controllers and flows, it is possible to avoid loops and network collapses. In order to realize this, all switches in the wheel topology must be SDN switches. The central switch requires a large degree Pt that equals $N-1$ and can take over a specific function: for example, the connection to an SDN controller. Another possibility is to expand the network with several SDN controllers and divide it into different areas. The satellite switches, which are star topologies in themselves, could be a local area with an independent SDN switch which could run the local SDN functions and applications in their area. A local star topology of one of the satellite switches is shown in Fig. 4. This local area can relieve the SDN controller in the center of the wheel topology and run its own SDN applications and serves as a backup in case of a failure of the central SDN controller. The local SDN controller can have access to applications that are only relevant to the local star and the local nodes and therefore do not have to leave the local star. Such a local area relieves the central SDN controller and still offers all SDN advantages. These areas could theoretically be implemented with any satellite switches, but it is necessary to consider the increased configuration effort that comes along with that. In special applications, it is possible to use only a virtual star topology or a virtual ring topology due to the unique design

TABLE I
Topology Characteristics

Topology	Pt	$\varnothing$	K	B	V_b
Wheel	1	4	1	$\lfloor \frac{N}{2} + 2 \rfloor$	$2(M + 2)(N - 1)$
Dual-Ring	2	$\lfloor \frac{N}{2} \rfloor$	2	2	$2N$
Star	$N - 1$	2	1	1	$2(N - 1)$
Bus	1	1	1	1	$2N$

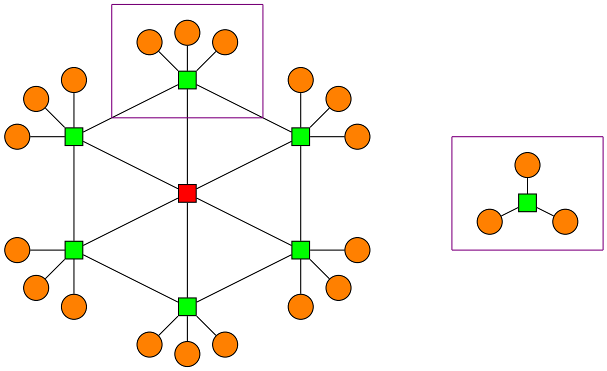

Fig. 4. local star in wheel topology with $N = 7$ and $M = 3$

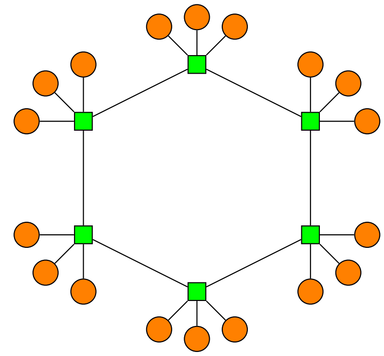

Fig. 6. logical ring topology in wheel topology

of the wheel topology. For this purpose, SDN can be used to create a logical star and a logical ring topology, see Fig. 5 and Fig. 6. In case of a logical star, with the SDN controller in the center, one would have a very powerful star node with the previously mentioned high degree of Pt. In case of a logical ring, the previously mentioned local SDN controllers could share the SDN tasks. Special use cases could be various parallel running multiprocessor tasks each deployed through the use of SDN in logical topologies. The wheel topology can be used very flexible and in combination with SDN it can be used for several purposes.

IV. Conclusion and Outlook

In this work, we proposed a new topology, called wheel topology, and presented the static characteristics of this topology. A possible implementation with SDN in a classic network was described. The next steps are to investigate the wheel topology with common network mechanisms, such as Link Layer Discovery Protocol (LLDP) and intent-based forwarding, and the simulation of the wheel topology. Different behaviours of the wheel topology will be observed, e.g. the behaviour when each node sends in every clock cycle. For this purpose, it is necessary to evaluate how large the buffers of the nodes and the switches have to be and what kind of operations result from the sending and receiving procedures. Potential problems, such as deadlocks, must be prevented with suitable rules and further adjustments.

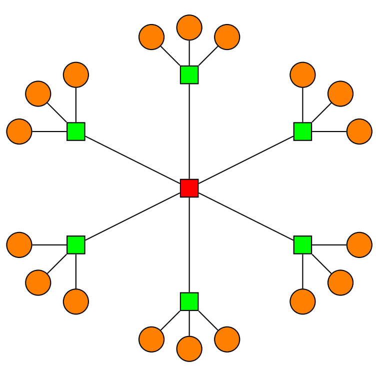

Fig. 5. logical star topology in wheel topology

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