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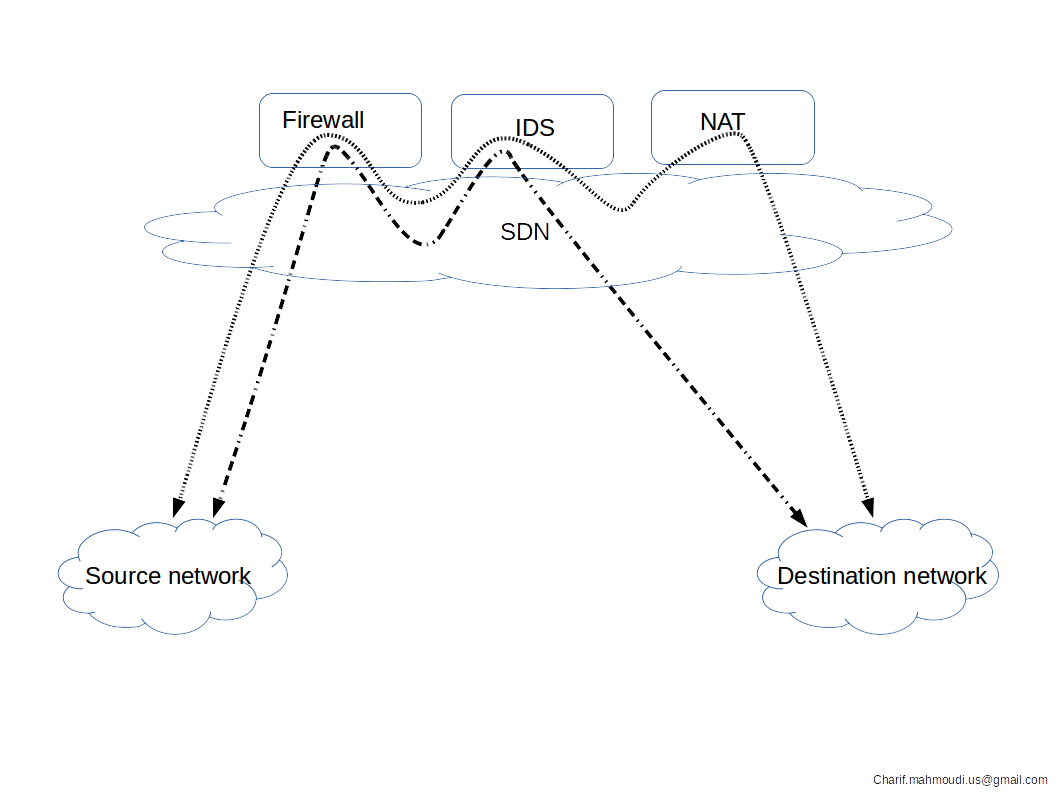
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*Abstract*—This article describes how Service Function Chaining (SFC) can be applied to enhance per-device flow control among the Internet of Things. This approach aim to enable a custom chain of Virtual Network Function (VNF) for every single IoT device. This article addresses the challenge related to the expansion of Software Defined Networking (SDN) to IoT devices over Internet. The contribution presented by this article is the extension of the Web of Things (WoT) architecture to support OpenFlow and enable integration of WoT virtual devices to the SDN network.

Keywords—component; formatting; style; styling; insert (key words)

# Introduction (*Heading 1*)

SFC is an approach that provides the ability to define an ordered list of a network services (Firewalls - L4-7, Network Address Translation - NAT, Intrusion Protection and Detection Systems - IDS & IPS). These services are then "composed" together in a virtual chain. SFC is a capability that uses SDN to create a service chain to set up suites or catalogs of connected services that enable the use of a single network connection for many services, with different characteristics.



SDN is the enabler of SFC as illustrated in Figure 1. The idea behind such an approach is to pipe the flows between two networks with different chaining according to the requirement associated with each single flow. The flow is forwarded to a set of middle-boxes that are implementations of VNFs.

WoT architecture can help to extend SFC to the edge of the network. WoT concept of virtual device, named “WoT Servient”, provides the access to, control and get the status and values from IoT physical devices. It offers a runtime and an API to build applications that runs on multiple environments according to the deployment scenarios. The virtual device is mainly composed from three layers:

* Protocol binding: to communicate with the other devices and users
* Runtime environment: offers an API for creating server functions which accepts request through WoT Interface from other clients.
* Applications: user code that can access to the hardware resources. it contains the logic and uses the API provided by the runtime to communicate with other devices.

The challenge addressed by this article is the extension of the SFC to the edge of the network. WoT virtual devices are good candidates to support this extension. To do so, we propose to adapt the runtime environment to make it OpenFlow aware. More over, we propose to build micro network functions as applications and pipe flows between them according to the flow rules.

As illustrated in Figure 2, extending SDN and VNF to the edge can enable a new degree of granularity in the control of the flow for every single device. Moreover, some functions can be deployed on the virtual device to implement device specific controls such as the Manufacturer Usage Description (MUD).

## Standard for SFC

In the Internet Engineering Task Force (IETF) SFC working group started a standardization effort relative to the categorization of these middle-boxes. The mobile use case (informational) draft by Haeffner et al. put these into 3 categories. Category 1 are general propose functions used by all services. This category includes:

* Deep packet inspection
* Firewall
* Network address translation
* Load-balancer

Category 2 are value added services that are specific to the cloud or the Internet service providers that includes:

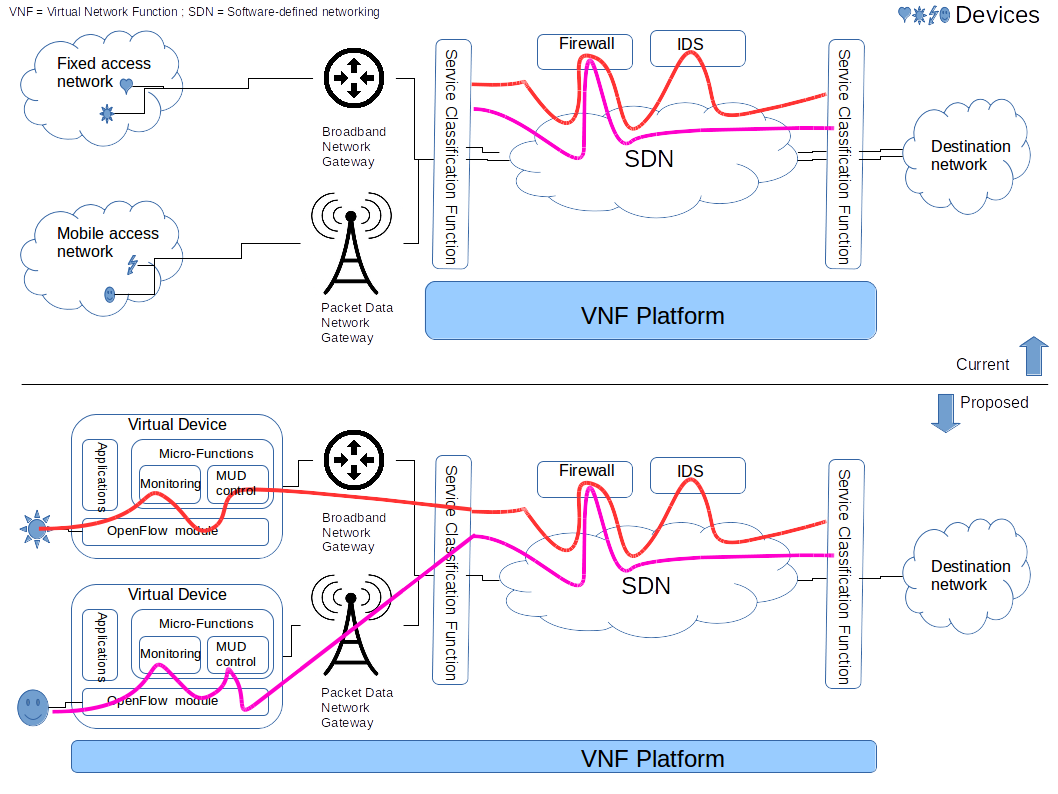
* Intrusion and malware detection
* Parental controls
* Lawful intersection
* Monitoring and analytic probes

Category 3 are mobile-specific that enhance the application for SFC is in mobile networks that includes:

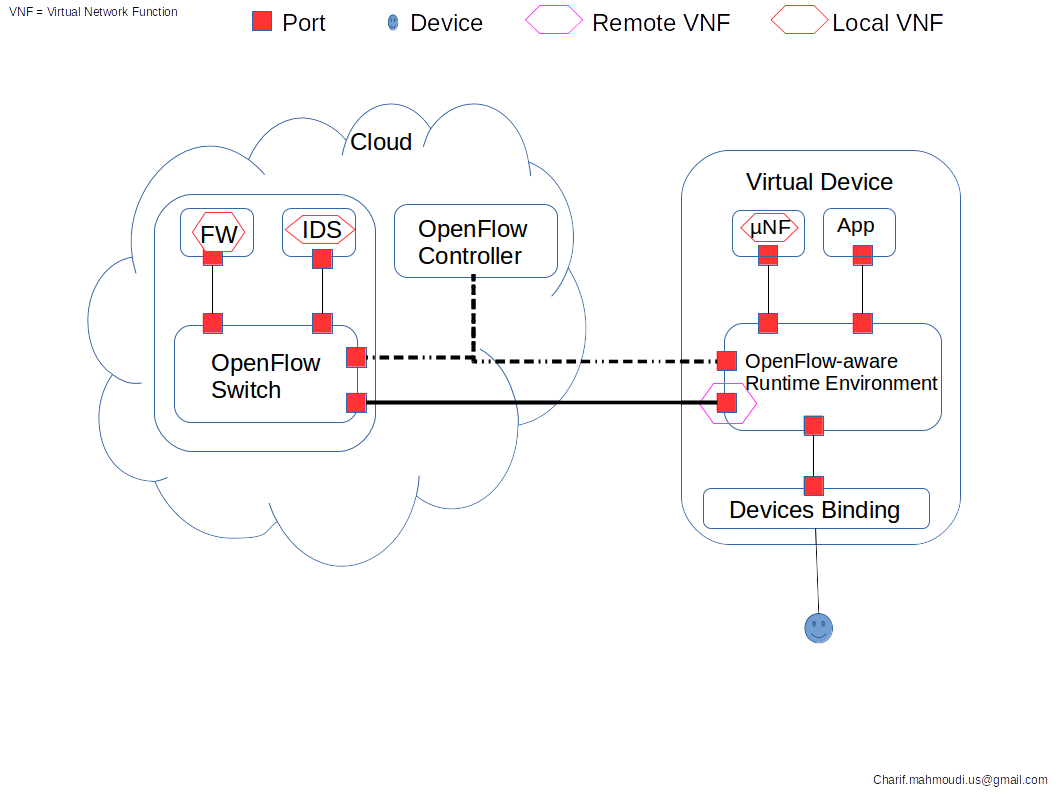
* WAN/TCP optimizer
* Video optimizer
* HTTP header enrichment
* Content filtering
* Content caching

## Architecture

The primary advantage of SFC is to automate the way virtual network connections can be set up to handle traffic flows for connected services. The WoT architecture introduces some capabilities we can leverage to extend the chain of function to the devices. One of the main components introduces by the WoT is WoT servient which is a virtual component associated with IoT devices. It enables accessing to the device's function as a web resource. WoT aims to normalize the access to the devices as web resources by both humans and other devices. WoT servient can be used to extend the VNF platform to the edge of the network. Virtual device (WoT Servient) can host lightweight or micro network functions. Moreover, virtual device should be aware of OpenFlow to enable chaining the local micro-functions with the remote network functions as illustrated in Figure 3.



The virtual devices are first class citizen in SDN in this architecture. the service classification consider the function available in both locally on the virtual device and on the remote location. The runtime environment should support integration with the SDN controller and act according the the rules pushed from the controller. the objective is not to implement a high throughput forwarder, the objective is to have a lightweight module that can pipe the flows between applications. knowing that the applications use an API to communicate between each others.



The architecture proposed by WoT is still accurate as the layers defined by the WoT still apply. Unlike the reference implementation, the runtime environment on this architecture limits the communications from/to the application according to the flow tables. this tables are filled by the SDN controller to enforce a specific SFC composed from the local and remote VNF. Figure 4 illustrate an example of integration with a controllers in the cloud. Deployment is not limited to the cloud as the controller and the functions can be deployed and managed by the Internet service provider.

## Deployment scenarios

WoT virtual devices are used on this architecture as a building block of the VNF platform. Deployment scenarios follows WoT scenarios with the three levels of deployment: end-devices, edge/fog, and cloud as illustrated in Figure 5. On all three levels, devices can communicate only with their corresponding virtual devices. All external communications uses the API provided by runtime environment.

Three scenarios are introduced by the extension of SDN to the virtual devices. According to the use case, flows can use local VNF, remote VNF, or a mix in hybrid mode. Specific networking infrastructure is required for every scenario.

* Local VNF: No integration with a remote SDN network is needed at the data plane. A link at the control plane is need to get the chaining configuration for the flows. As the all the chaining happens locally on the virtual device, the data plane is limited to the virtual device boundaries.
* Remote VNF: Requires integration with both data and control planes. Even if the virtual device does not apply any VNF to the flow, the runtime environment need to get the first remote VNF in the chain to forward the traffic to it from the applications.
* Hybrid mode: It requires also integration with both data and control planes. Runtime environment pipes the traffic to the local VNF before forwarding it to the first remote VNF on the chain.

## Conclusion

We discussed in this article the extension of SDN control plane to the WoT virtual devices to enhance the granularity of the control on IoT devices.

This template, modified in MS Word 2007 and saved as a “Word 97-2003 Document” for the PC, provides authors with most of the formatting specifications needed for preparing electronic versions of their papers. All standard paper components have been specified for three reasons: (1) ease of use when formatting individual papers, (2) automatic compliance to electronic requirements that facilitate the concurrent or later production of electronic products, and (3) conformity of style throughout a conference proceedings. Margins, column widths, line spacing, and type styles are built-in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

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Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

## Units

* Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive.”
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*a**b*    

Note that the equation is centered using a center tab stop. Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(1),” not “Eq. (1)” or “equation (1),” except at the beginning of a sentence: “Equation (1) is ...”

## Some Common Mistakes

* The word “data” is plural, not singular.
* The subscript for the permeability of vacuum **0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o.”
* In American English, commas, semi-/colons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
* A graph within a graph is an “inset,” not an “insert.” The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).
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* In your paper title, if the words “that uses” can accurately replace the word using, capitalize the “u”; if not, keep using lower-cased.
* Be aware of the different meanings of the homophones “affect” and “effect,” “complement” and “compliment,” “discreet” and “discrete,” “principal” and “principle.”
* Do not confuse “imply” and “infer.”
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* There is no period after the “et” in the Latin abbreviation “et al.”
* The abbreviation “i.e.” means “that is,” and the abbreviation “e.g.” means “for example.”

An excellent style manual for science writers is [7].

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Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include ACKNOWLEDGMENTS and REFERENCES, and for these, the correct style to use is “Heading 5.” Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract,” will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced. Styles named “Heading 1,” “Heading 2,” “Heading 3,” and “Heading 4” are prescribed.

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1. Table Styles

| Table Head | Table Column Head | | |
| --- | --- | --- | --- |
| Table column subhead | Subhead | Subhead |
| copy | More table copya |  |  |

1. Sample of a Table footnote. *(Table footnote)*
2. Example of a figure caption. *(figure caption)*

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity “Magnetization,” or “Magnetization, M,” not just “M.” If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write “Magnetization (A/m)” or “Magnetization (A ( m(1),” not just “A/m.” Do not label axes with a ratio of quantities and units. For example, write “Temperature (K),” not “Temperature/K.”

##### Acknowledgment *(Heading 5)*

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g.” Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

##### References

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1. G. Eason, B. Noble, and I.N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955. (*references*)

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To have non-visible rules on your frame, use the MSWord “Format” pull-down menu, select Text Box > Colors and Lines to choose No Fill and No Line.

1. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.
2. I.S. Jacobs and C.P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G.T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.
3. K. Elissa, “Title of paper if known,” unpublished.
4. R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.
5. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
6. M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.