6G Self-Synthesising Networks For An Immersive World

Prof Mischa Dohler
Fellow of the IEEE, Royal Academy of Engineering, Royal Society of Arts & IET Chair Professor, King's College London Cofounder, various companies Composer, various albums

9 September 2021
Telco Trends

1. Growth Trend

KPIs: (i) rate, (ii) # of devices, (iii) criticality
*inverse of delay & outage*

2. Consolidation Trend

Order(s) of Magnitude

1G → 2G → 3G → 4G → 5G → 6G

Time or Generations

niche → consumer → industry
# 5G and 6G KPIs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IMT-Advanced (4G)</th>
<th>IMT-2020 (5G)</th>
<th>Networks-2030 (6G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak data rate</td>
<td>DL: 1Gbps</td>
<td>DL: 20Gbps</td>
<td>1Gbps</td>
</tr>
<tr>
<td></td>
<td>UL: 0.5Gbps</td>
<td>UL: 10Gbps</td>
<td></td>
</tr>
<tr>
<td>User experienced data rate</td>
<td>10Mbps</td>
<td>100Mbps</td>
<td>0.1ms</td>
</tr>
<tr>
<td>Peak spectra efficiency</td>
<td>DL: 15bps/Hz</td>
<td>DL: 30bps/Hz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UL: 6.75bps/Hz</td>
<td>UL: 15bps/Hz</td>
<td></td>
</tr>
<tr>
<td>Mobility</td>
<td>350km/h</td>
<td>500km/h</td>
<td></td>
</tr>
<tr>
<td>User Plane latency</td>
<td>10ms</td>
<td>1ms</td>
<td></td>
</tr>
<tr>
<td>Connection density</td>
<td>1,000 devices/km²</td>
<td>1,000,000 devices/km²</td>
<td></td>
</tr>
<tr>
<td>Energy consumption</td>
<td>1 (normalized)</td>
<td>1/10x of 4G</td>
<td></td>
</tr>
<tr>
<td>Mobile data volume</td>
<td>0.01Tb/s/km²</td>
<td>10Tb/s/km²</td>
<td></td>
</tr>
</tbody>
</table>

Source: 5G-PPP

Machine Age, as humans cannot absorb that data

New KPI?
Holographic Society: If a human body is mapped in holographic tiles with colour, depth, etc transmitted, then this will need a transmission rate of 4.32Tbps (Nvidia?).


Spatial compute limitations, i.e. the main shortcomings of VR and spatially flat AR, have been overcome by 6d.ai. Their pioneering mobile edge rendering delivers engaging AR/XR experiences.
6G will likely be the dawn of a Machine-Driven Era. It is an era, where we won’t define applications/services anymore; it will be done by machines.

These services will likely appear/disappear in milliseconds. Our current era of discrete services will be replaced by a continuous spectrum of highly volatile services.
From 5G Architecture ...
... To 6G Architecture
Research started by M Dohler, King’s College London, in 2018.

<table>
<thead>
<tr>
<th></th>
<th>Autonomous Networks</th>
<th>Self-Synthesising Networks*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Human-Driven</td>
<td>Human-Driven</td>
</tr>
<tr>
<td>Systems Design</td>
<td>Human-Driven</td>
<td>Automated</td>
</tr>
<tr>
<td>Standards/Prototyping</td>
<td>Human-Driven</td>
<td>Reduced/Automated</td>
</tr>
<tr>
<td>Deploy/Configure</td>
<td>SON for Config</td>
<td>SON</td>
</tr>
<tr>
<td>Operations</td>
<td>SON</td>
<td>SON</td>
</tr>
</tbody>
</table>

8-10 Years Acceleration of Innovation Cycle

Self-Synthesising Networks

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To achieve self-synthesising networking capabilities:
1. casting novel inventions into innovation design templates;
2. translating these innovation design templates into machine-readable meta-language (e.g. UML/XML/OpenAPI3);
3. verifying operational consistency of the latter (e.g. through B-Language); and
4. subsequently translating it into operational software (e.g. C/C++/Python).
## Meta-Natural Language Processing:

![Code Generation Class Diagram](image)

### Table 6.7: Generated Programs - Measuring the accuracy of the best variation on its lowest performing attributes

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Input</th>
<th>Output</th>
<th>Generated Program (Python)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>2, -1, 3, -4, 5, 3, 2, 4, 4</td>
<td>3</td>
<td><code>a=[2, -1, 3, -4, 5, 3, 2, 4, 4]</code></td>
</tr>
<tr>
<td></td>
<td>Count (&lt; 0)</td>
<td>0</td>
<td><code>b=len(list(filter(lambda x: x &lt; 0, a)))</code></td>
</tr>
<tr>
<td>Test 2</td>
<td>-4, 2, 4, 5, 6, 7, 8, 3</td>
<td>5, 7, 3</td>
<td><code>a=[-4, 2, 4, 5, 6, 7, 8, 3]</code></td>
</tr>
<tr>
<td></td>
<td>Filter (odd)</td>
<td>1, 3, 5, 7</td>
<td><code>b=list(filter(lambda x: x%2==1, a))</code></td>
</tr>
<tr>
<td>Test 3</td>
<td>-2, 3, 3, 4, -5, -6, -7, 1</td>
<td>-2</td>
<td><code>a=[-2, 3, 3, 4, -5, -6, -7, 1]</code></td>
</tr>
<tr>
<td></td>
<td>(Head)</td>
<td></td>
<td><code>b=a[0]</code></td>
</tr>
<tr>
<td>Test 4</td>
<td>1, 3, -5, 7, 3, 4, 5, -2</td>
<td>-2</td>
<td><code>a=[1, 3, -5, 7, 3, 4, 5, -2]</code></td>
</tr>
<tr>
<td></td>
<td>(Last)</td>
<td></td>
<td><code>b=a[-1]</code></td>
</tr>
<tr>
<td>Test 5</td>
<td>1, 1, 1, 1, 1, 1, 1, 1</td>
<td>1, 2, 3, 4, 5</td>
<td><code>a=[1, 1, 1, 1, 1, 1, 1, 1]</code></td>
</tr>
<tr>
<td></td>
<td>(Scan1 (+))</td>
<td></td>
<td><code>b=list(accumulate(a, operator.add))</code></td>
</tr>
</tbody>
</table>
Self-Synthesising Networks

O-RAN RICs:

Enrichment data from network management, network functions and other sources

O-RAN Control Loops

Non-RT RIC

Near RT RAN Intelligent Controller (RIC)
xApp1 xApp2 .......... xAppN

RAN Metrics Database

3GPP’s NWDAF:

Annex A (normative): OpenAPI specification

A.1 General

The present Annex contains an OpenAPI [11] specification of HTTP messages and content bodies used by the
Ndwlaf_EventsSubscription and the Ndwlaf_AutoAnalytics API.

This Annex shall take precedence when being discrepant to other parts of the specification with respect to the encoding of
information elements and methods within the API(s).

NOTE 1: The content and structure, as well as conditions, e.g. for the applicability and allowed combination of
structures or values, are expressed in the OpenAPI definitions for defined in other parts of the
specification also apply.

Informative copies of the OpenAPI specification file contained in this 3GPP Technical Specification are available on
the portal. Follow the server in the following locations (see clause 5.8 of the 3GPP TS 23.509 [18] for further information):

- https://www.3gpp.org/ftp/Specs/archive/3GPP/A16999
- https://www.3gpp.org/Members/3GPP/Release

NOTE 2: To fetch the OpenAPI specification file after CT4a plasny meeting for Release 15 in the above links
"Plasny" must be replaced with the date the CT Plasny occurs, in the form of year-month (yyyy-mm), e.g. for CT4a meeting "Plasny" must be replaced with value "2018-05" and "Release" must be replaced with value "R15-07".

A.2 Ndwlaf_EventsSubscription API

OpenAPI 3.1.0

Scheme: "ndwlaf_EventsSubscription"

Field: ndwlaf_EventsSubscription

Description: 3GPP TS 23.509 V6.2.0 (2020-05)

P. System: Network Data Analytics Services

URL: https://www.3gpp.org/ftp/Specs/archive/3GPP/releases/08-05/

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### Disruption: Machine Age

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2nd Disruption: Self-Synthesis

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A global Internet of Skills requires a truly global ultra-low latency:

1. Network Congestion
2. Application Delay
3. Speed of Light

Human Cortex

London - LA

10ms

End-to-End “Slicing”

Artificial Intelligence (Mobile Edge Cloud)

No Compression

3rd Disruption: Global ULL
“We started to design 3G when the Internet wasn’t even truly around; and we started to design 4G when the smart phone wasn’t invented yet.”

Hans Vestberg, then-CEO of Ericsson and current CEO of Verizon

“We started to design 5G when low-latency Synchronised Reality wasn’t around; and we started to design 6G when machines were not self-synthesising yet.”
We launched [www.6GFutures.uk](http://www.6GFutures.uk) in July 2021 with the ambition to become UK’s Turing Institute in Future Networks.

Focus is on breakthrough innovation in telecoms with tangible impact through standards, spinouts, academic publications, etc.
Thank you!