The Broadband Forum

Delivering on the promise of broadband by enabling smarter, faster networks and a thriving ecosystem

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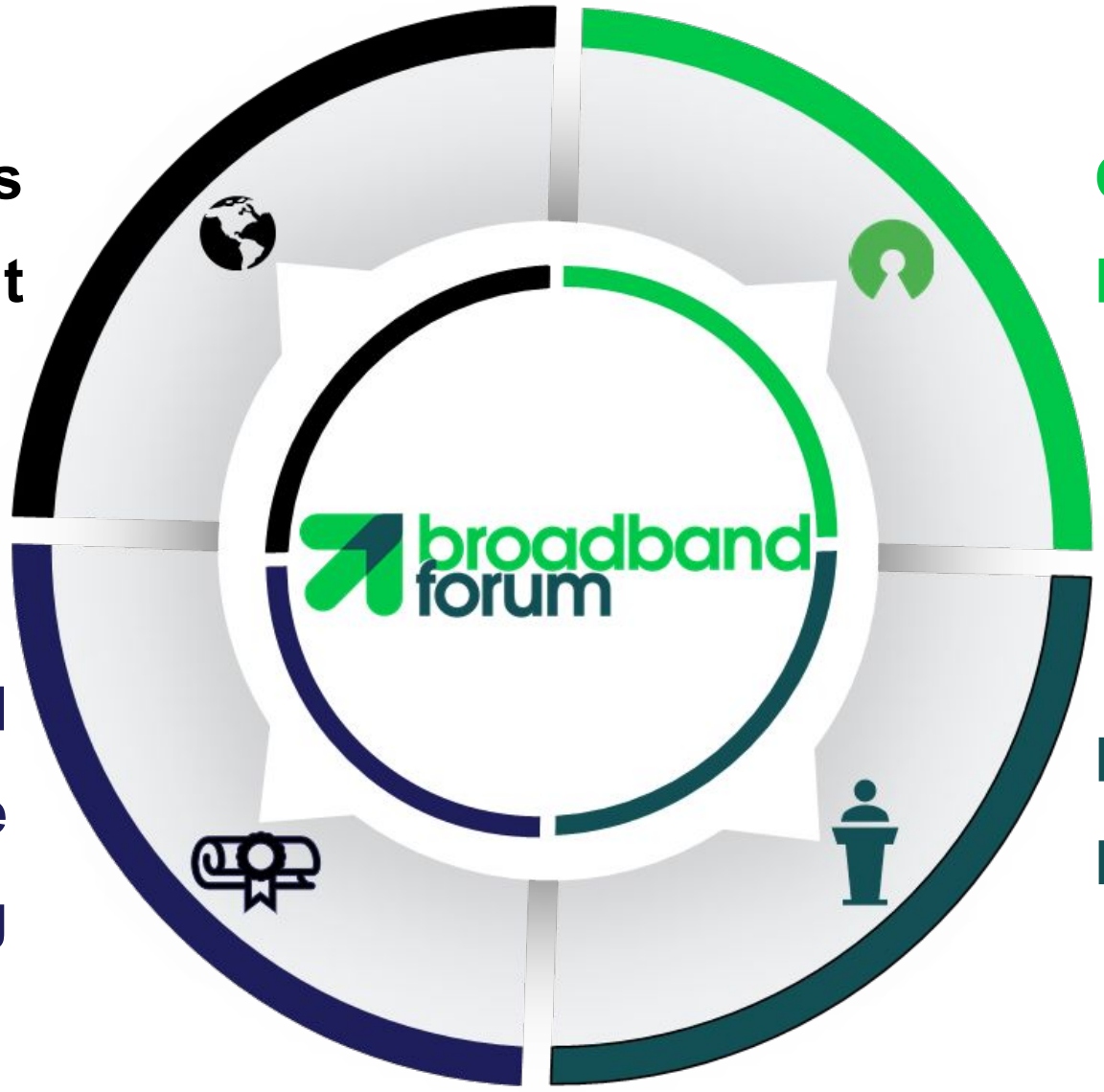
BBF Deliverables

Global Open Standards Development

Open Broadband Projects



Certification and Performance Testing

BASe: Industry Education

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BBF Areas of Focus and Innovation

Connected Home

- *TR-069 (CWMP)*
- *User Services Platform (USP)*
- *Device Requirements*
- *Wi-Fi Performance*

5G

- *5G FMC*
- *5G Transport*

Cloud

- *CloudCO*
- *Virtualization*
- *Disaggregation*
- *FANS*
- *AI & ML*

Access/Next

- *Fiber*
- *Copper*
- *Performance Measurement & Analysis*
- *Quality of Experience*

Agenda

Subscriber Network Device Management

Quality of Experience Delivered

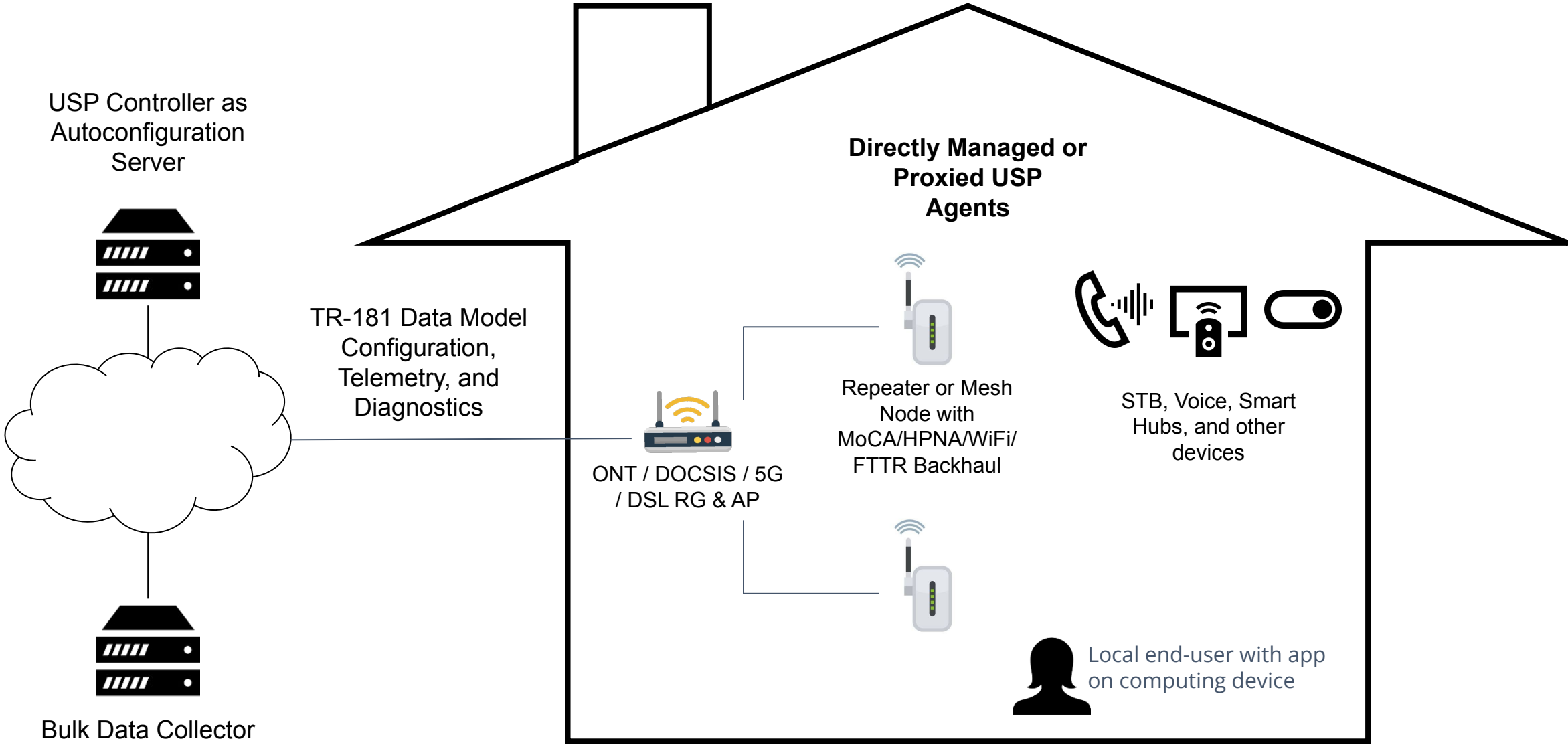
IP-Layer Capacity and OB-UDPST Project

BBF Certification Programs

The Broadband User Services Work Area

- The User Services Platform (USP/TR-369)
- The Device:2 data model for connected devices (TR-181)
- The App-Enabled Services Gateway (in partnership with members from organizations developing open-source gateway/CPE stacks, i.e., RDK, prpl
- Defining modular requirements for residential gateways (TR-124)
- Defining and supporting operator-grade managed Wi-Fi & overall home connectivity (WT-488)
- Works with FAN group on clear management roles between USP and OMCI (TR-142)

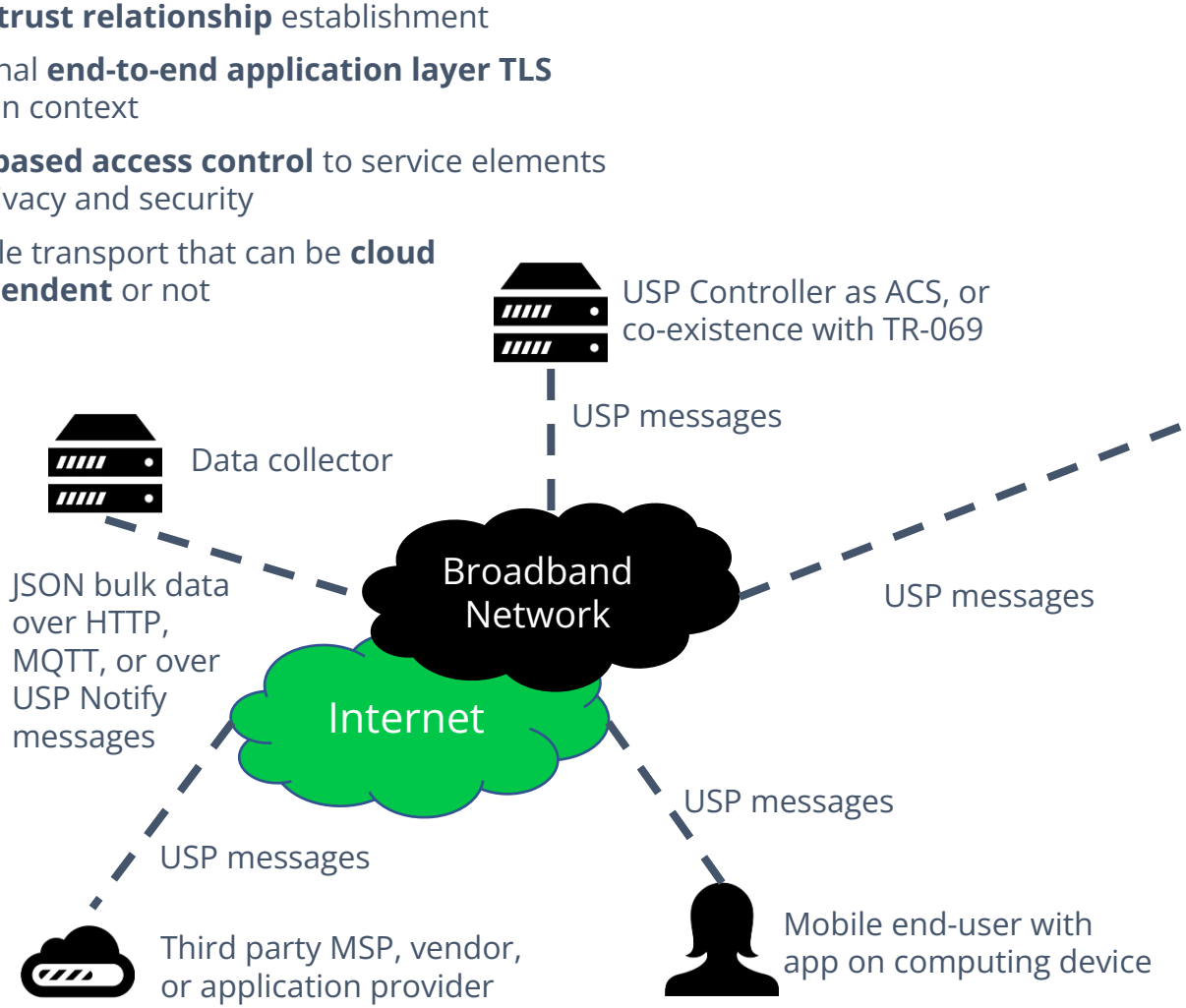
The BBF Management Architecture

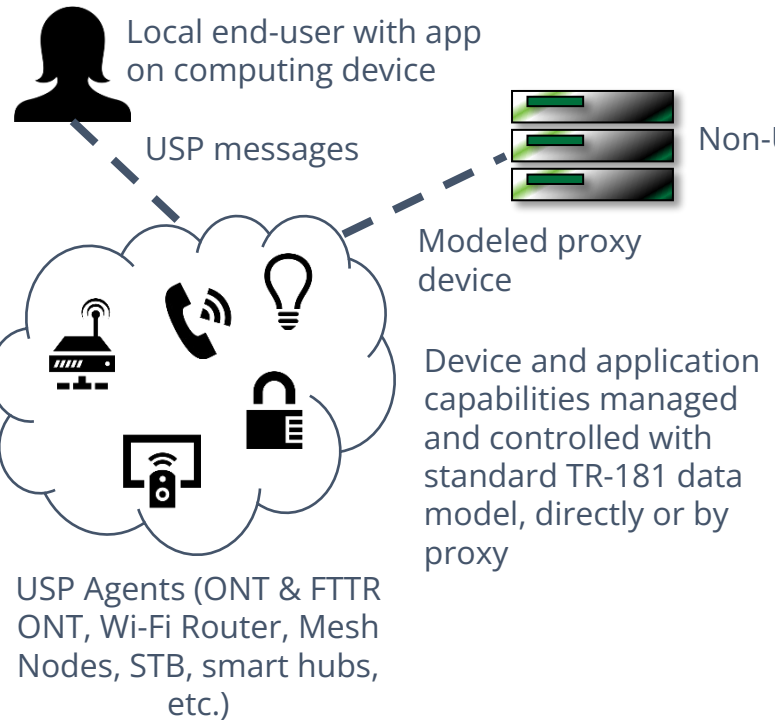


USP ecosystem

USP Controllers and USP Agents have:

- **Persistent connections** to reduce handshakes
- Clear **trust relationship** establishment
- Optional **end-to-end application layer TLS** session context
- **Role-based access control** to service elements for privacy and security
- Flexible transport that can be **cloud independent** or not

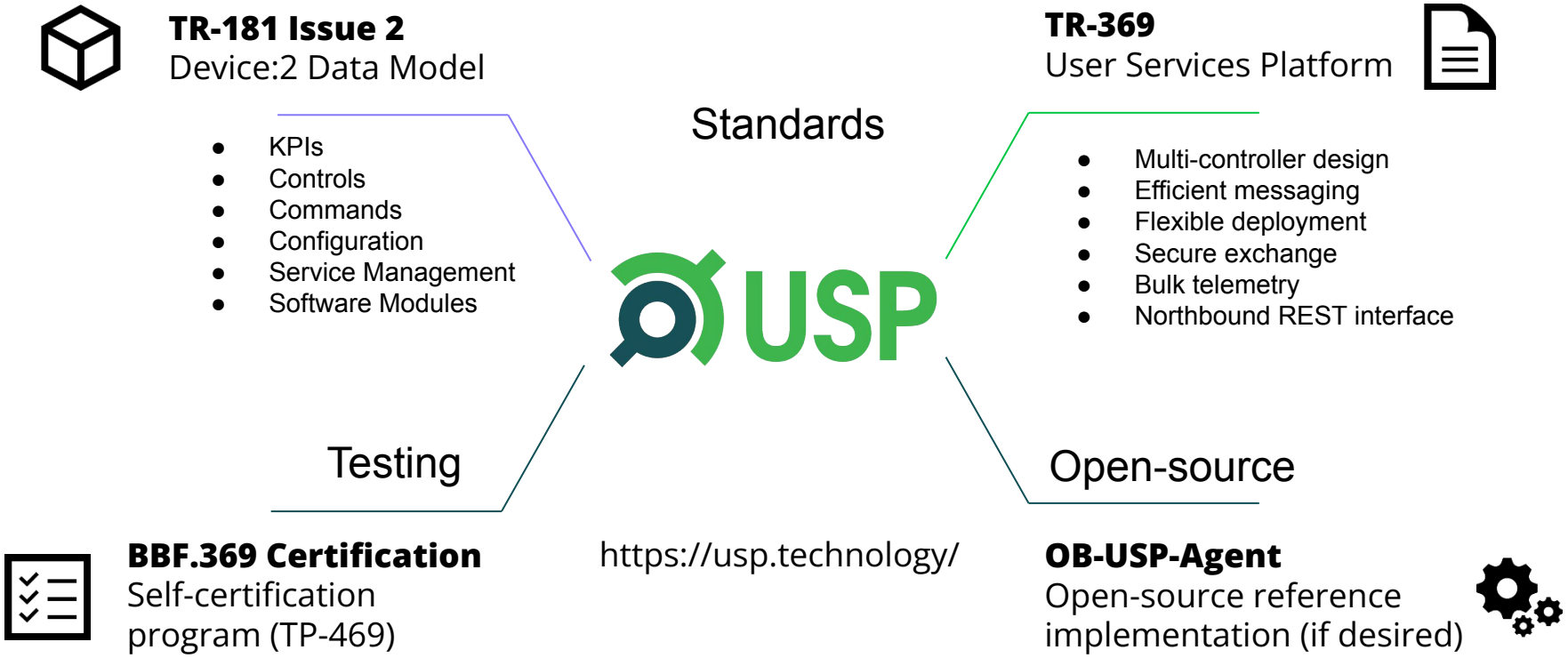




- Network setup and config
- Network, security and privacy control
- Software container management
- Wi-Fi management
- Firmware and software upgrades
- Diagnostic commands
- Bulk data telemetry
- Custom commands & events
- IoT sensors and controls

TR-181/Device:2 Data Model Capabilities

What makes up the User Services Platform?

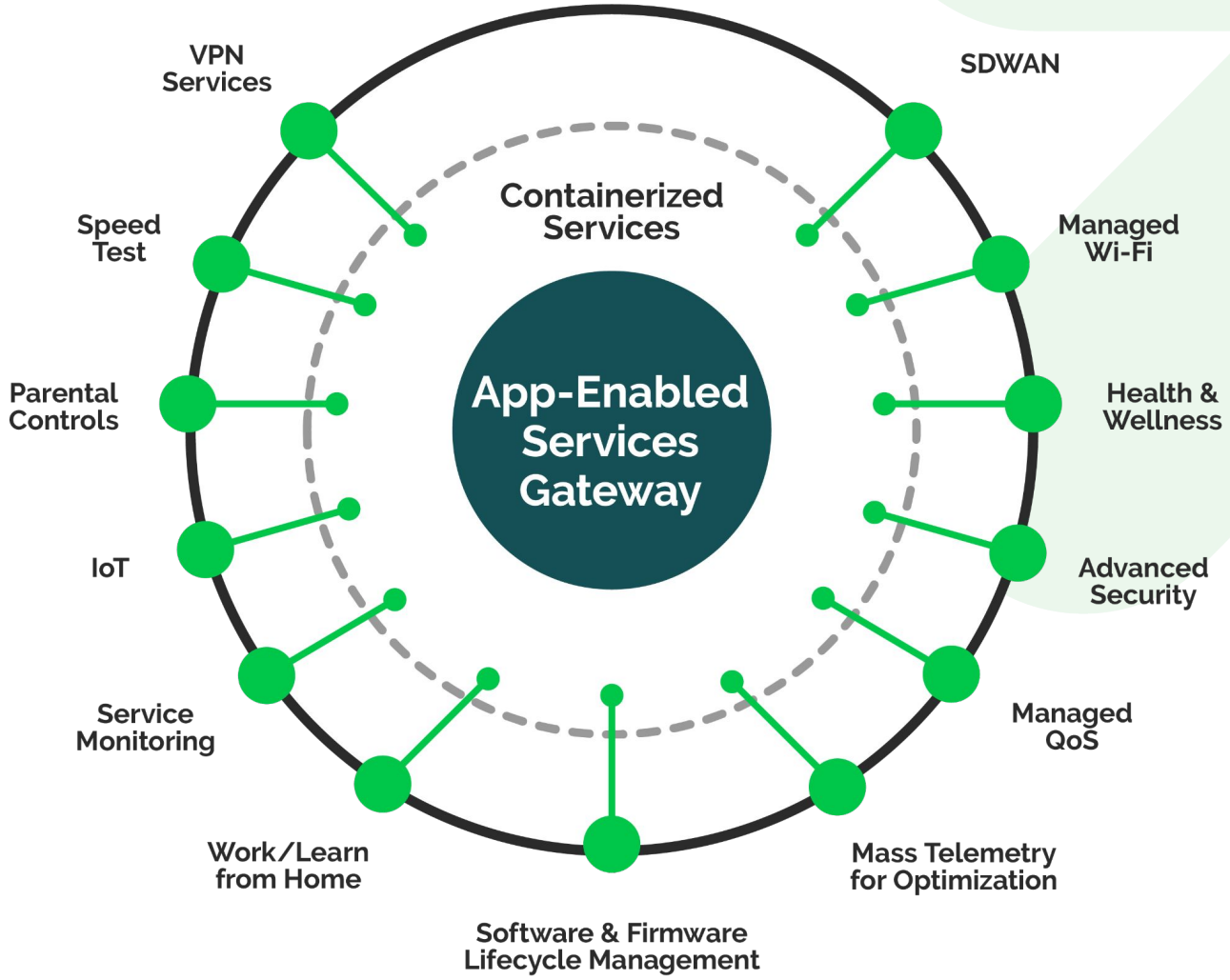


Complemented by:

Wi-Fi Data Elements Certification
QuickTrack certification method
https://www.wi-fi.org/discover-wi-fi/Wi-Fi-Data-Elements

WT-492 and the Rise of the App-Enabled Services Gateway

Services Driven Modular Software RG



In the era of Gigabit Broadband, our industry is ready for the next step

How useful?

Functionality
e.g. Synchronisation support
(for small-cell/mobile backhaul)

How "Good"?

Quality
Latency & Consistency
(stability, stationarity & reliability)

How Much?

Quantity
Bandwidth

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Issues

Faster speeds are delivering diminishing returns in user satisfaction

- We need to move beyond “bandwidth” as the sole proxy for end-user QoE

Many applications are affected by short-term variations in packet delivery

- We need to measure distributions not averages

Many application-specific performance metrics and measurements exist

- But don’t provide much support for root-cause analysis in the network

We need a metric that:

- Is a strong predictor of the performance of **any** application
- Is applicable across and along the digital delivery chain
- Allows localization of performance issues for root-cause analysis

Applications are distributed computations

- Computational components **must** exchange information via the network
- All exchanges are *delayed* by the network: some are *lost*
- The characteristics of that delay and loss affect the application performance
- In the gigabit era, network capacity is no longer the limiting factor for many applications

Delay is the price we pay for being distributed

Loss is the price we sometimes have to pay for using statistically shared infrastructure

User experience is becoming more and more dependent on network quality characteristics

Applications are increasingly affected more by delay and loss than by capacity

Aspects of QED

Capture application demands

In a way that is:

- Unbiased,
- Objective,
- Verifiable
- Adaptable to new applications

So as to:

- Give operators more visibility of what performance they should support
- Encourage OTT suppliers to reduce applications' demands on the network

Measure service delivery

- In relation to application needs
  - Is a network service fit-for-purpose for a particular application?
- Dealing with the heterogeneous digital delivery chain
  - By reliably locating performance issues;
- Avoiding unreasonable loads on the network.

A new framework

- QED is a *new framework* for relating network and application performance
  - It gives far greater insight into network issues than simple min/average/max latency and jitter measurements
  - It is a better predictor of quality of experience and application outcomes than speed tests

- QED has *many applications* for broadband service providers including:
  - Root-cause analysis for network operations
  - Access technology performance characterization
  - Consumer broadband quality KPI
  - In-home network optimization.

Nature of performance

In an ‘ideal world’, systems would always respond instantaneously

- and without exceptions/failures/errors

In practice this doesn’t happen

- there is always some delay and some chance of failure: some ‘attenuation’ of quality

Thus, performance is a *privation*

- the *absence* of attenuation
- like ‘darkness’ or ‘silence’

Quantity also matters

- require a certain *rate* or *volume* of responses with a *given bound on attenuation*

Measure of performance: quality attenuation (ΔQ)

ΔQ is a **measure** of the 'quality attenuation' of an *outcome*

- The extent of deviation (the 'delta') from 'instantaneous and infallible'
- Nothing in the real world is perfect so ΔQ **always exists**

ΔQ is **conserved**

- A delayed outcome can't be 'undelayed'
- A failed outcome can't be 'unfailed'

ΔQ can be **traded**

- E.g., accept more delay in return for more certainty of completion

ΔQ is **mathematically rigorous**

- It can be decomposed and re-combined

Application view of networks

Every distributed application relies on the network to translocate information from one place to another.

The application doesn't care *how* the network does this: it only cares *how long it takes* (and if it *fails*)

- I.e., the **quality attenuation** its offered load experiences:
  - "Insufficient bandwidth" means: "At the offered load, the *instantaneous packet loss/delay* exceeds the *acceptable performance bounds* of the application"
  - Connectivity failure means: "quality attenuation is total".

Layered network protocols insulate the application from most of the network details, just leaving the ΔQ.

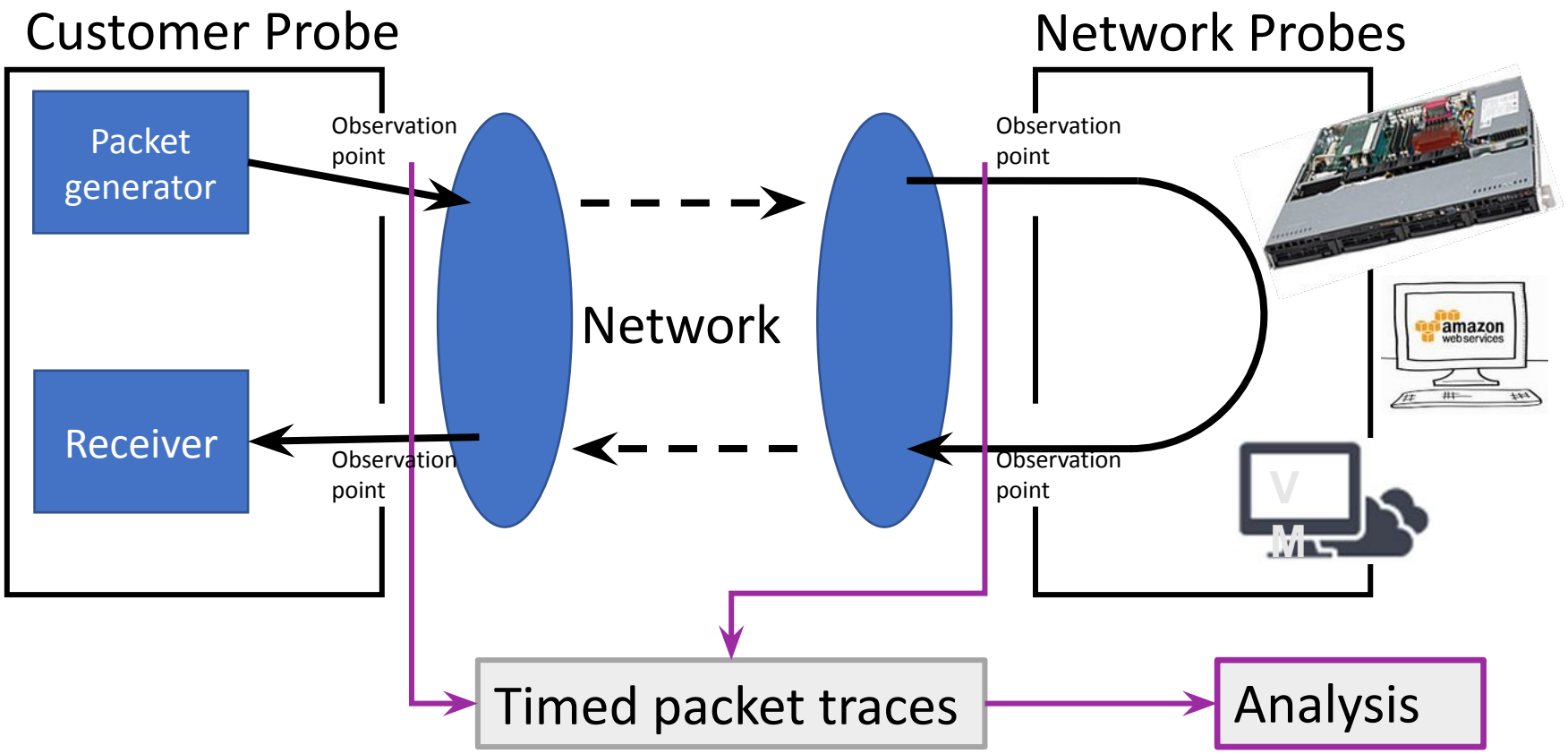
Summary: ΔQ

Quality Attenuation:

- Is **distributed**
  - Outcomes can begin and end in different places
- Combines **delay** and **failure**
  - E.g., packet delay and loss rate
- Is **statistical**
  - Measuring distributions, not just averages
- Goes **beyond bandwidth**
  - The real *application requirement* is for ‘a quantity of quality’
  - ‘Capacity’ is a limiting case

Measuring ΔQ using test packets

Typically a low rate (<32kbit/s) test stream of time-stamped packets of variable size is sent end-to-end round-trip to measure ΔQ in both directions



Details specified in TR-452.1 and TR-452.2

- Each packet is sent through a loop between the edge probe and the network probe.
- The packets are timed in and out of the test equipment
- Traces are matched and compared to analyse the performance.
- **Both round-trip <u>and</u> each direction**

Not all Bandwidth is Created Equal!

$\Delta Q_{|V}$

Queueing/buffering

- 50 Mbit/s on an empty network is **NOT** the same as 50 Mbit/s on a loaded network

$\Delta Q_{|S}$

Serialisation Delay

- 50 Mbit/s on a 100 Mbit/s Ethernet port is **NOT** the same as 50 Mbit/s on a 10 Gbit/s port
- $1/10^{th}$ of 100Mbit/s is **NOT** the same as 10 Mbit/s

$\Delta Q_{|G}$

Physical Layer

- 50 Mbit/s on GPON is **NOT** the same as 50 Mbit/s on 4G

Performance is about a more than just having 'enough bandwidth'!

Use cases for Broadband Service Providers

Network Health Check

- Is the architecture appropriate?
- Are the network assets being fully used?
- Are there loading issues?
- Are the configurations consistent with performance goals?
- Is the capacity planning process effective?
  - Does it meet the requirements of the services and applications?
  - If not, what are the impairments?
  - Where are they occurring?
- What new services could be supported?
  - What would be the impact on existing services if they were rolled out?

Root Cause Analysis (RCA) Tool

- Re-routing
- Load balancing
- Packet fragmentation
- Profile changes
  - DSL Dynamic Line Management (DLM)
  - Seamless Rate Adaptation (SRA)
- CPE processor maxed out
- Misconfigured schedulers
  - Queue saturation
  - Bufferbloat etc.
- WiFi versus WAN Demarcation

Use cases for Broadband Service Providers

Network Architecture Design/Analysis

- Performance Characterization
  - Network/access Technology
  - Network Equipment
- Performance implications of locating
  - Virtual Network Function (VNF)
  - Content cache
  - CDN node

Quantitative Timeliness Agreements (QTAs)

QTAs relate ΔQ budgets to application requirements and outcomes, and can be used for:

- Service Level Agreement (SLA) for business customers
- Avoiding performance hazards in Wholesale Fixed Access
- Consumer Broadband Quality Performance KPIs

Applications for the In-home network

Use-cases apply to the in-home network as well as the access network:

- Equipment selection
- Fault detection
- Root cause analysis
- Automation of network configuration
- Dynamically selecting the best link in a mesh home network

Two-part Problem Statement and Progress

1. As Internet access speeds increase into the Gigabit range, the current, **ad hoc TCP-based methods** measuring **“Internet Speed” often produce a significant underestimate of IP Capacity.**
   - Virtually all popular ad-Hoc Methods are TCP-based!
2. The Industry is transitioning to a new Transport protocol, that will supplant TCP => QUIC/UDP – **existing measurement methods should evolve**

- How should we measure **Internet access performance** now? (and not just “speed”, but also latency under working-load/saturation)
- Our Approach Motivated by
  - comparison tests
  - straightforward specifications
  - “Running Code”

Expanded Roles for UDPST (UDP Speed Test)

1. Maximum IP-Layer Capacity Parameter and Method of Measurement (UDP-based test)
   - UDP Allows Measurements at Max Capacity
   - Other working conditions, if desired
   - Can “manage” competing traffic if needed: users are never idle
2. Simultaneous Measurement of
   - Latency: 1-way Delay Variation (Jitter), Round-trip Time and variation
   - Reordering, Duplication
3. Application Traffic stream generation and computation of interactivity factor

Certification Program Goals

- Driving broadband forward through validated interoperability and open source collaboration
- Enable interoperability, through well defined requirements, specifications, and published test plans
- Provide network operators with resources to make well informed decisions when planning deployments
- Reduce resources required for testing by individual operators, through common result outcomes of certification testing
- Ensure highest quality testing, through approved Open Broadband Laboratories

PON ONU Certification

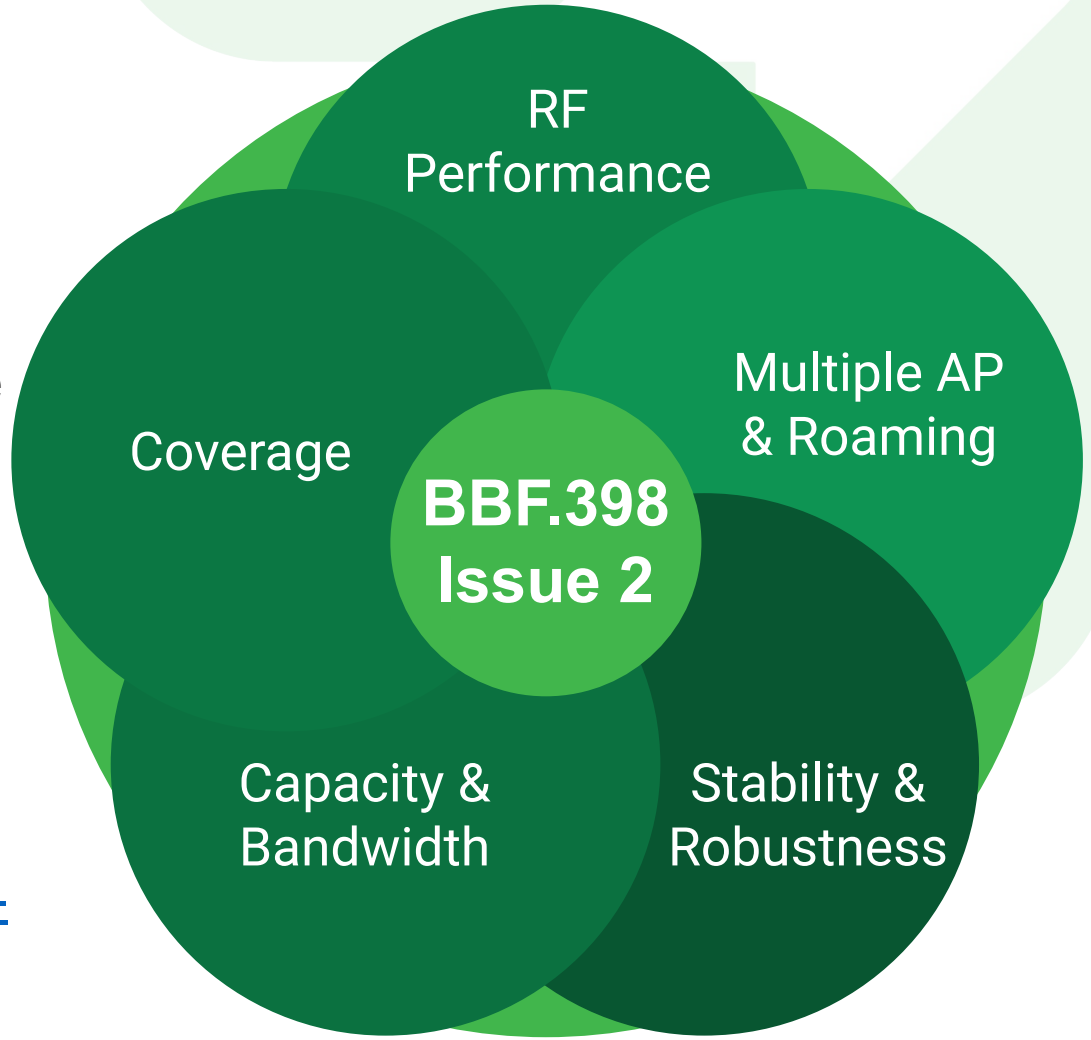
- Certification testing defined in TP-247
  - Testing focused on the ONU's OMCI implementation
  - GPON & XG-PON & XGS-PON devices supported
  - Testing Coverage:
    - Service Configuration (i.e. VLANs, Priority Queues, Multicast)
    - Device Management & Monitoring (i.e. firmware upgrades, alarm reporting, MIB sync)
    - Enhanced OMCI & randomization provides more coverage of the OMCI state machines
    - Testing utilizes OLT Emulator to allow full control of OMCI protocol
  - 100's ONU's Certified & Listed
    - https://www.broadband-forum.org/testing-and-certification-programs/bbf-247-gpon-onu-certification
    - Residential & business grade devices
    - SFP devices & integrated RG devices
- Interoperability Testing in TP-255
  - Requirements based on BBF PON architecture
  - Similar to certification testing, but requires interoperability with OLT equipment

USP Certification

- USP Certification, Test Plan TP-469
  - Focused on testing of USP Agent protocol implementation
  - Coverage similar to TR-069 (i.e. core protocol, security, processes, management, etc).
  - Support for optional parts of USP, through profiles.
- TR-069 Certification, Test Plan TP-069
  - Focused on testing of CPE protocol implementation
  - Coverage: core RPCs (Get / Set / etc.) & processes (bootstrap, etc.)
  - Security: ssl certificates and timers
  - Device Management: firmware upgrade, factory reset
- Certification Resources
  - Both programs are “self-testing” using the approved tools - Participants use tools, submit final results for review / approval
  - https://www.broadband-forum.org/testing-and-certification-programs/bbf-069-certification
  - https://www.broadband-forum.org/testing-and-certification-programs/bbf-369-usp-certification

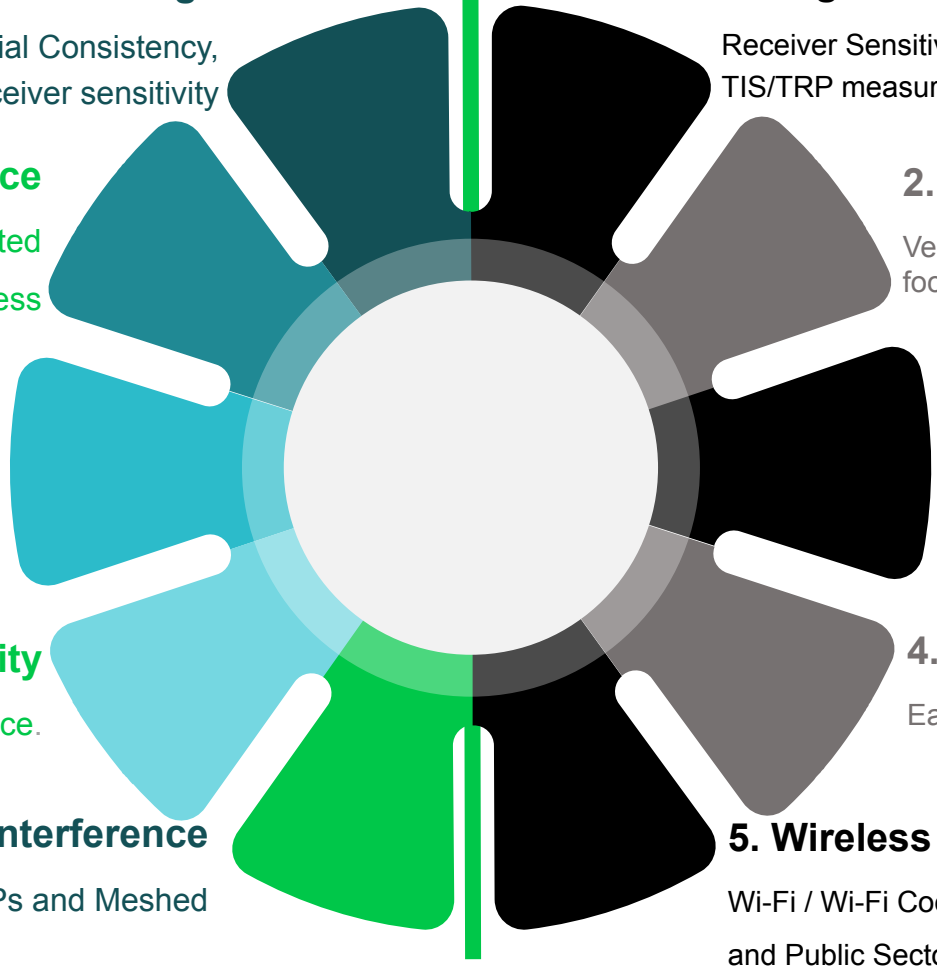
BBF.398 Carrier Grade Wi-Fi

- TR-398: Wi-Fi Residential & SOHO Performance Testing
- Wi-Fi AP device performance
  - Technology Coverage: Wi-Fi4, Wi-Fi 5, and Wi-Fi 6
  - Testing Categories: RF Performance, Coverage, Capacity, Stability, Interference
  - Focus on performance within real deployment and usage scenarios
    - Two Spatial Streams common to devices like mobile phones & laptops
    - No need to test legacy protocols like 802.11a or b/g, or uncommon uses like 802.11n on 5 GHz
- Issue 3 publication is imminent
  - Wi-Fi 6E, Mesh Deployment, Backhaul Scenarios, Parameter Accuracy
- Device Listings: https://www.broadband-forum.org/testing-and-certification-programs/bbf-398-carrier-grade-wifi



BBF.398 GRADE Wi-Fi

Existing Wi-Fi Device Testing



1. Coverage

Range v Throughput, Spatial Consistency, Receiver sensitivity

2. Performance

Maximum Throughput, Maximum connected stations, Airtime fairness

3. Capacity

Multi-Station performance, Downlink MU-MIMO, Basic Roaming performance

4. Stability

Long-term stability, AP coexistence.

5. Interference

With 3rd Party devices, RGs, APs and Meshed

1. Regulatory Testing:

Receiver Sensitivity, conducted transmit power, TIS/TRP measurements

2. Interop & Connectivity testing

Verify connectivity with set of reference devices, not focused on performance”

3. Wi-Fi Functionality Features

Testing on features such as WPA, WPA3, WPS, WMM, QoS

4. Initial Performance Testing

Early mesh and roaming test cases.

5. Wireless Co-existence

Wi-Fi / Wi-Fi Coexistences especially for Enterprise and Public Sector

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Thank you!

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