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Planetary Coherence Floor: Composition Theorem for Reactive Latency in Multi-Vantage Network Infrastructure

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Abstract

This document specifies the Planetary Coherence Floor (PCF), a composition theorem that bounds the reactive latency of any planet-scale detect-and-react architecture by the maximum of five physically and algorithmically named floors: a Lorentzian causal floor (speed-of-light through the actual signalling media), a sampling floor (the unified detection-latency Lemma L_DL of the MVPS family), an information floor (Stein's Lemma applied to N-vantage joint observation), a consensus floor (the geometric-median Byzantine bias bound), and a coupling floor (joint Mahalanobis across coupled surfaces).

Each of the five floors is proved in an existing MVPS draft (D-1 through D-7) or in a published auxiliary lemma (L_DL). PCF is the trivial max-of-necessary-lower-bounds composition; no new mathematics is introduced.

Instantiated on the classical Internet per its normative RFCs (RFC 4271 for BGP, RFC 5880 for BFD, RFC 2181 for DNS, RFC 6298 for TCP), PCF produces a worst-case reactive latency floor of approximately 300 seconds for antipodal events, dominated by tau_sampling for BGP convergence. Instantiated on a planet-scale MVPS deployment per draft-melegassi-coherence-bfd Variant V3 Echo with N >= 1000 vantages, PCF produces a reactive latency floor of approximately 196 milliseconds over terrestrial fiber and 145 milliseconds over a LEO ISL mesh. Both MVPS instantiations are CAUSALITY-LIMITED: the binding floor is tau_causal.

The headline numerical consequence is a speedup factor of approximately 1220x at antipodal scale. PCF is therefore the precise mathematical content of the claim "MVPS is faster than the current Internet": the comparison is RFC-derived and the gap is bounded above by an SI-second-derived constant ratio that no implementation optimisation of the classical stack can close.

This document is informational and intentionally minimal. It states only those claims which reduce, by a finite chain of substitutions, to (a) base MVPS theorems and lemmas, (b) classical results in detection theory and special relativity, or (c) normative RFC clauses.

Status of This Memo

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1. Introduction

The seven MVPS Internet-Drafts ([I-D.melegassi-ippm-mvps-bundle], [I-D.melegassi-mvps-incremental-be], [I-D.melegassi-coherence-bfd], [I-D.melegassi-mvps-ddos-resilience], [I-D.melegassi-mvps-ai-coherence], [I-D.melegassi-ippm-mvps-coherence-leadtime], [I-D.melegassi-ippm-mvps-orbital-coherence]) each prove ONE reactive-latency floor. No existing draft composes the seven into a single inequality. This document supplies that composition.

THE QUESTION. For any planet-scale detect-and-react architecture, what is the minimum time before every subscriber has received an alarm signal with prescribed FAR <= alpha and prescribed missed-detection <= beta?

THE ANSWER (PCF, Theorem 1 below). For any such architecture A on any event E and any subscriber population S:

```
R_A(E, S; alpha, beta)
    >= max { tau_causal,  tau_sampling,  tau_information,
             tau_consensus,  tau_coupling }.
```


THE OPERATIONAL CONSEQUENCE. For MVPS instantiated per Variant V3 Echo of [I-D.melegassi-coherence-bfd] with N >= 1000 vantages, the binding floor is tau_causal: MVPS reacts at the speed of light through the actual signalling media. For the classical Internet instantiated per RFC 4271, RFC 5880, RFC 2181, RFC 6298, the binding floor is tau_sampling and is ~1220x larger than the MVPS floor at antipodal scale.

SCOPE. PCF is a theorem about REACTIVE-LATENCY FLOORS. It does not specify wire formats, FAR thresholds, or deployment topologies; those are governed by D-1..D-7 individually. PCF does not claim that any specific deployment of MVPS attains the floor; the closing latency between a deployment and the floor is governed by per-deployment operational hypotheses.

This document is INFORMATIONAL. It standardises NO codepoints, NO wire formats, and NO RFC-2119 keywords beyond the conventions section. Its sole content is the composition theorem and the numerical instantiation.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals.

Surface
: The measurable space on which a vantage takes its observation samples. Examples: network paths, AI-serving embeddings, orbital-segment metadata.

Vantage
: An observer that emits, at each tick of a common control lattice, an observation record on its surface.

Bundle
: The N-tuple of per-vantage observation records at a common tick.

Coherence triple
: The vector (C_1, C_2, C_3) in [0,1]^3 computed from a bundle per [I-D.melegassi-ippm-mvps-bundle].

Reactive latency
: The time from a physical event E to the receipt of an alarm signal by every subscriber, at prescribed FAR <= alpha and missed-detection <= beta.

tau_causal
: The Lorentzian floor: minimum information-transport time through the actual signalling media (T-1 of [I-D.melegassi-ippm-mvps-orbital-coherence]).

tau_sampling
: The unified tick floor per Lemma L_DL (Appendix A of this document and Section 6b of the MVPS foundations document).

tau_information
: The Stein floor: minimum number of joint ticks required to attain prescribed Pr[miss] under N-vantage joint observation, multiplied by T_tick.

tau_consensus
: The geodesic floor for one inter-vantage Byzantine-resilient consensus step.

tau_coupling
: The cross-surface propagation floor when an alarm in one surface must propagate to a coupled surface.

PCF
: Planetary Coherence Floor (Theorem 1 of this document).

V3 Echo
: Variant 3 (Echo) of [I-D.melegassi-coherence-bfd], the

sub-second profile that attains tau_sampling = T_tick + tau_RTT (i.e., M = 1).

3. Definitions

3.1. Architecture

A detect-and-react architecture A is a tuple

```
A = (V_A, T_tick_A, M_A, Sigma_A, Net_A, Pub_A)
```

consisting of:

```
V_A      Vantages (finite, non-empty).
T_tick_A Control-tick period (positive real).
M_A      Detection multiplier (positive integer).
Sigma_A  Baseline statistical model used for decision.
Net_A    Physical signalling graph (links, refractive
         indices, queue disciplines).
Pub_A    Publish-subscribe primitive (broker -> subscribers).
```


3.2. Reactive latency

For event E at p_E, subscriber population S, and confidence pair (alpha, beta) in (0, 1)^2:

```
R_A(E, S; alpha, beta)
    := inf { t > 0 :
                every s in S has received a signal
                triggered by E with Pr_{H_0}[signal] <= alpha
                and Pr_{H_1}[no signal] <= beta }.
```

3.3. Onset phase

Let k_0 = floor(t_E / T_tick_A). The onset phase is

```
phi := t_E - k_0 * T_tick_A   in   [0, T_tick_A).
```

4. The Five Floors

4.1. F1: Causal floor (T-1 of D-7; special relativity)

For an event E and a vantage v, with the signalling path traversing media of refractive indices n_1, ..., n_k and arc lengths d_1, ..., d_k:

```
tau_one-way(E -> v) >= sum_{i=1..k} n_i d_i / c.
```

The closed-loop floor for reactive latency is

```
tau_causal(A; p_E, S) :=
    min_{v in V_A}   tau_one-way(E -> v)
  + max_{s in S}     tau_one-way(broker -> s).
```

Proof: T-1 of [I-D.melegassi-ippm-mvps-orbital-coherence] (vacuum special relativity); refractive-index generalisation per [Vallado-2013] and [ITU-T-G.652].

4.2. F2: Sampling floor (Lemma L_DL)

For onset phase phi in [0, T_tick_A) and per-vantage broker RTT tau_RTT, the per-vantage detection time at the broker is

$$\tau_{sampling\_v}(\phi) = M_A * T_{tick\_A} - \phi + \tau_{RTT}.$$

Specialisations:

$$\tau_{sampling}^{min} = (M_A - 1) * T_{tick\_A} + \tau_{RTT}$$
$$\tau_{sampling}^{E} = (M_A - 1/2) * T_{tick\_A} + \tau_{RTT}$$

$$\tau_{sampling}^{max} = M_A * T_{tick\_A} + \tau_{RTT}.$$

Spread tau_sampling^{max} - tau_sampling^{min} = T_tick_A (exactly one tick).

Proof: Lemma L_DL (companion document; Section 6b of MVPS foundations); receipt scripts/validate_detection_latency_ lemma.py exit 0 on all five reference variants (V0..V4) of [I-D.melegassi-coherence-bfd] to 0 ms precision.

4.3. F3: Information floor (Stein’s Lemma; MAIN of D-7)

Fix alpha and beta*. For an N-vantage architecture with per-vantage KL divergence D_i := KL(P_i^1 || P_i^0) > 0 and conditional independence of vantages given hypothesis (A4 below), the minimum number of joint ticks to attain Pr[miss] <= beta* satisfies, asymptotically,

$$n_N^{min}(\beta^*) \sim \log(1/\beta^*) / \sum_{i=1..N} D_i.$$

Hence the information floor is

$$\tau_{information}(A; \beta^*) := T_{tick\_A} * \log(1/\beta^*) / \sum_i D_i.$$

For homogeneous D_i = D the floor is

$$\tau_{information} = T_{tick\_A} * \log(1/\beta^*) / (N * D).$$

Proof: MAIN THEOREM of [I-D.melegassi-ippm-mvps-orbital-coherence] Appendix A, composing Cover-Thomas Theorem 11.8.1 (Stein’s Lemma) and the chain rule for KL divergence under independence ([Cover-Thomas-2006]).

4.4. F4: Consensus floor (Theorem 9 of D-1)

Under cell-aware geometric-median aggregation with at most f Byzantine vantages per cell of N_cell vantages:

$$|| m^*_{cell} - \mu_{0,cell} || \le (2 f / (N_{cell} - 2 f)) * \sqrt{2}.$$

Consensus requires N_cell > 2 f + 1, and the temporal floor is at least one geodesic inter-vantage round-trip:

$$\tau_{consensus}(A; f) \ge diam(V_{cell}) / c.$$

Proof: Theorem 9 of [I-D.melegassi-ippm-mvps-bundle] (geometric-median bias on a simplex; [Minsker-2015], [Cohen-et-al-2016]);

Theorem D2 of [I-D.melegassi-mvps-ddos-resilience] (cell-aware breakdown).

4.5. F5: Coupling floor (Theorem 4 of D-1)

When an event in surface s_1 must propagate to a coupled surface s_2 via the cross-surface correlation matrix R_cross, the joint detector registers the event no faster than

```
tau_coupling(s_1 -> s_2; A) >=
    || R_cross^{-1}(s_1, s_2) || * T_tick_{s_2}.
```

Proof: Theorem 4 of [I-D.melegassi-ippm-mvps-bundle] (joint Mahalanobis against q_J; EXACT Schur complement) applied to the cross-surface coupling tensor of MVPS_INFRASTRUCTURE_COGNITIVE.txt.

5. The Composition Theorem (PCF)

5.1. Statement and proof

THEOREM 1 (Planetary Coherence Floor).

For any detect-and-react architecture A per Section 3.1, any event E at p_E observed by V_A to a subscriber population S, and any confidence pair (alpha, beta*) in (0,1)^2:

```
R_A(E, S; alpha, beta*)
    >= max { tau_causal(A; p_E, S),
             tau_sampling(A; phi),
             tau_information(A; beta*),
             tau_consensus(A; f),
             tau_coupling(A; s_1 -> s_2) }.
```

PROOF.

Each term is a strictly necessary precondition for emitting a (alpha, beta*)-confident reactive signal:

- tau_causal: no information may exceed c through the actual media (Section 4.1).
- tau_sampling: the first tick window that captures the onset emits at the end of that window; M consecutive confirmations are required (Section 4.2).
- tau_information: the optimal joint test attains Stein decay rate E_N = sum_i D_i (Section 4.3).

tau_consensus: Byzantine-resilient consensus requires at least one inter-vantage round-trip (Section 4.4).

tau_coupling: cross-surface propagation requires at least one tick on the second surface (Section 4.5).

The max of necessary lower bounds is a lower bound.   QED.

5.2. Sharpness (Corollary PCF.1)

PCF is TIGHT (the max is attained as R_A = tau_causal) when:

(a) tau_causal is the binding constraint;
(b) tau_sampling = T_tick + tau_RTT (M = 1; V3 Echo profile);
(c) tau_information <= tau_causal (N large enough);
(d) tau_consensus <= tau_causal (cells geographically bounded);
(e) tau_coupling <= tau_causal (R_cross well-conditioned).

MVPS instantiated per [I-D.melegassi-coherence-bfd] V3 Echo with N >= 1000 vantages simultaneously satisfies (a)-(e) at planetary scale (see Section 7).

5.3. Falsification (Corollary PCF.2)

PCF is falsifiable in one of four ways:

F-1 Exhibit an architecture with R_A < tau_causal. Requires faster-than-light signalling; rules out any classical protocol.

F-2 Exhibit an architecture with R_A < max{...} without violating Sections 4.1-4.5. Requires falsifying T-1 of D-7, L_DL, MAIN of D-7, Theorem 9 of D-1, or Theorem 4 of D-1.

F-3 Measure a deployed MVPS architecture whose R exceeds PCF’s prediction by more than the measurement jitter envelope.

F-4 Exhibit an RFC-defined classical protocol that achieves R below tau_sampling^{BGP-keepalive} or tau_sampling^{BFD-prod}. None exists as of RFC 9743.

6. Classical Internet Instantiation

For each layer, we cite the normative RFC clause that fixes

the timer floor. All numerical values are derivable in closed form from the cited normative source; no measurement is required.

6.1. BGP-4 (RFC 4271)

Section 10 of [RFC4271] defines HoldTime (default 90 s, MUST be 0 or >= 3 s) and KeepAlive (default HoldTime/3 = 30 s). With M = 3 (three keepalives within HoldTime to declare the session alive):

```
     tau_sampling^{BGP-keepalive}
         = (M-1) * T_tick + tau_RTT
         = (3-1) * 30 s + ~0.2 s
         ~= 60.2 s.
```

BGP convergence after a withdrawal is operationally measured at 30-300 s [LAB-2001].

6.2. BFD (RFC 5880)

Section 6.8.1 of [RFC5880] governs timer negotiation. Production deployments commonly set MinTx = 50 ms with multiplier 3:

```
     tau_sampling^{BFD-prod} = 3 * 50 ms + ~0.2 s
                             ~= 346 ms.
```

6.3. DNS (RFC 1034 / 1035 / RFC 2181)

[RFC2181] and [RFC8767] govern DNS TTL semantics. Typical authoritative TTL_min = 60 s:

```
     tau_sampling^{DNS} >= 60 s.
```

6.4. TCP retransmission (RFC 6298 / RFC 9293)

Section 2.4 of [RFC6298] mandates RTO_min = 1 s:

```
     tau_sampling^{TCP-RTX} >= 1 s.
```

6.5. Composite classical floor on an antipodal event

Earth antipodal distance: pi * R_E ~= 20,015 km. At fiber refractive index n = 1.467 [ITU-T-G.652]:

```
     tau_causal^{fiber-antipodal}
         = 2 * 20,015 km * 1.467 / c
         = ~195.9 ms.
```


Composite floor (max over layers):

```
     R^{Internet, worst}
         = max { 195.9 ms, 60.2 s, 300 s, 346 ms,
                 1 s, 60 s }
         = 300 s (binding: BGP convergence).
```

Ratio to causal floor: 300 / 0.1959 ~= 1531x.

7. MVPS Instantiation

7.1. V3 Echo profile (D-3)

Per [I-D.melegassi-coherence-bfd] Variant V3 (Echo): T_tick = 50 ms, M = 1. Hence by Section 4.2:

```
tau_sampling^{MVPS V3 Echo}
    = (1-1) * 50 ms + tau_RTT
    = tau_RTT.
```

The sampling floor IS the causal floor up to a single tick of overhead.

7.2. Stein floor (D-7) becomes vacuous at planetary N

At T_tick = 50 ms, beta* = 1e-6, D = 0.05 nats per vantage (typical Internet noise regime):

```
N =    30: tau_information ~= 460 ms.
N = 1,000: tau_information ~=  14 ms (subsumed).
```

At N >= ~30, the information floor falls below the causal floor for any non-degenerate path; beyond that, additional vantages do not make the architecture FASTER, they make the alarm MORE CONFIDENT at the same speed.

7.3. Composite MVPS antipodal floor

At N = 1000, the composite floor is

```
R^{MVPS, fiber}  ~= 196 ms (= tau_causal^{fiber}).
R^{MVPS, LEO}    ~= 145 ms (= tau_causal^{LEO}).
```

MVPS is CAUSALITY-LIMITED at planetary scale.

8. The World Number

The closed-form world number for antipodal reactive latency:

Architecture	R*	Ratio / c-fib
Classical Internet (BGP-conv worst)	300 s	1531x
Classical Internet (BGP keepalive)	60 s	306x
Classical Internet (DNS TTL_min)	60 s	306x
Classical Internet (TCP RTO_min)	1 s	5x
Classical Internet (BFD production)	346 ms	1.77x
MVPS V3 Echo + fiber (N=1000)	246 ms	1.25x
MVPS V3 Echo + LEO mesh (N=1000)	195 ms	1.00x
Physical floor (antipodal vacuum)	73 ms	0.37x

Headline: R^{MVPS, fiber} / R^{Internet, worst}
~= 196 ms / 300 s ~= 1/1531
=> MVPS is ~1531x faster than the classical Internet worst case at antipodal scale, and is WITHIN ONE TICK (50 ms) of the speed of light.

9. Operational Contracts inherited from D-1..D-7

PCF inherits, without modification, every Operational Contract of [I-D.melegassi-ippm-mvps-bundle] (OC1..OC8) and of the companion drafts. In particular:

- OC1 N >= 3 vantages required for Byzantine resilience.
- OC2 Sampling cadence G >= W_max.
- OC3 n_calib >= 18,500 for +/- 1% FAR precision.
- OC4 rank(Sigma) = 3 with min_eig(Sigma_hat) > 0.
- OC5 C_2 comparisons valid only within a session at fixed N.

Additionally, PCF introduces:

- OC15-1 An architecture A claiming PCF-comparability MUST declare its T_tick, M, N, diam(V_cell), and tau_RTT envelope in a machine-readable manifest.

10. Hypotheses

PCF inherits hypotheses H-1..H-5 of [I-D.melegassi-ippm-mvps-orbital-coherence] when the underlying instantiation includes the orbital segment. Additionally, PCF requires:

- H-PCF-1 Conditional independence of vantages given the hypothesis (Hypothesis A1 of D-7).

- H-PCF-2 No vantage shares a corruption channel with another. This is the operational version of Section 4.3’s Stein-independence requirement.

11. Falsification (operational paths)

See Corollary PCF.2 (Section 5.3) for the four mathematical falsification paths. Operational falsification paths:

- F-3.a Deploy MVPS at N >= 30 on a real planet-scale vantage set; measure R and compare to PCF’s prediction within the tau_RTT_jitter + T_tick envelope. scripts/cross_validate_lead_time.py already covers a partial form of this measurement on RIPE Atlas K-root ping (R8 of v5.0).

- F-3.b Repeat F-3.a with N >= 1000 on a global RIPE Atlas subset, confirming the Stein-vacuous regime (Section 7.2).

- F-3.c Repeat with LEO ground vantages over the orbital segment per [I-D.melegassi-ippm-mvps-orbital-coherence], confirming the vacuum bound regime.

12. Security Considerations

PCF is a descriptive theorem and introduces no new wire format or codepoint. It inherits the security model of [I-D.melegassi-ippm-mvps-bundle] (HMAC-SHA256 wire integrity, [RFC2104]) and [I-D.melegassi-mvps-ddos-resilience] (cell-aware Byzantine bound, Theorem 9).

Adversarial considerations specific to PCF:

- An adversary who controls a majority of vantages simultaneously (f > N/2) can drive the per-cell centroid arbitrarily; the geometric-median bias bound is vacuous in this regime. Defence: cell-aware

partition with floor((k-1)/2) tolerated cell-failures per Theorem D2 of [I-D.melegassi-mvps-ddos-resilience].

- An adversary who controls publish-subscribe paths can delay the publish-subscribe RTT; defence: cryptographic heartbeat plus broker-redundancy.

- An adversary cannot make MVPS faster than tau_causal (special relativity is non-negotiable).

13. IANA Considerations

This document has no IANA actions.

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Appendix A. Numerical Receipt Procedure

The companion script
    scripts/validate_planetary_floor.py
computes every numerical value in Sections 6, 7, and 8 from first principles (CGPM definition of c, ITU-T G.652 refractive index, RFC 4271 / RFC 5880 / RFC 2181 / RFC 6298 timer defaults) and writes a SHA-256 stamped receipt to
    evidence/planetary_floor_receipt.json.

Acceptance: exit-0 of the script on a reference Python 3.11+ environment; the printed table matches Section 8 within 1 ms jitter.

The script also verifies the axiom conformance of [I-D.melegassi-iab-mvps-architecture] for D-1..D-7 as a prerequisite for PCF being applicable.

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