
DPDK
DATA PLANE DEVELOPMENT KIT
Thread-safe High Performance Pseudo-random Number Generation

# Agenda

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- Introduction
- Use cases
- API
- Pre-19.08 Implementation
- Goals for 19.08
- Implementation
- Initial Seeding
- Bounded PRNG
- Questions

# Pseudo-random Number Generator (PRNG)

- An algorithm for generating a sequence of numbers
- Each number approximates a truly random number
- Deterministic
- Sequence determined by initial state – the seed

# Use Cases

- Network protocol implementations
- Functional and performance testing
- Important aspects
  - Good statistical properties (e.g. uniformity and passing various tests)
  - Thread safety
  - Efficiency
  - Security

# PRNG API

- <rte_random.h>
- uint64_t rte_rand(void);
  - Generates 64-bit pseudo-random number
- void rte_srand(uint64_t seed);
  - Provides opportunity for a user-specified seed

# Pre-19.08: Implementation

- rte_rand()/rte_srand() wrappers around lrand48()/srand48()
- *rand48() is a part of the Single UNIX Specification and glibc
  - Uniform distribution
  - Range [0 – (2^31-1)]
  - Not thread-safe (shared state) [DPDK bug 114]
  - Implemented with a 48-bit linear congruential generator (LCG)
- rte_rand() uses two lrand48() calls – high and low bits
- Only generates 62-bit of randomness
  - Bit 31 and 63 are always zero [DPDK bug 276]

# 19.08: Goals

1. Provide thread safety to allow use from lcore threads
2. Keep things simple and API/ABI backward-compatible
3. Higher-quality generated values (including truly 64-bit values)
4. Improved performance
5. Improved API documentation
6. Improved initial seeding
7. DPDK performance test suite extension
8. Unbiased, bounded PRNG

*Initial goal*

*Final goal*

# 19.08: Out of Scope

- No rte_rand32()
  - Faster (~35% less overhead), but 64-bit still very fast
- No support for multiple distributions - stay uniform-only
- No support for multiple PRNG algorithms
- …for advanced functionality, use external library

# 19.08: General Design

- rte_rand() / rte_srand() API remains unchanged
- Introduce per-lcore PRNG
  - No rte_rand_r() or any user-managed state
  - Makes rte_rand() MT safe (for lcore worker threads)
- rte_srand() still MT unsafe
  - For use during application initialization
  - Seed used by each lcore is <global-seed>+<lcore_id>
- <rte_random.h> functions are moved from “static inline” in header file to regular, non-static functions
  - ABI addition, but backward compatible

# 19.08: Tausworthe Generator

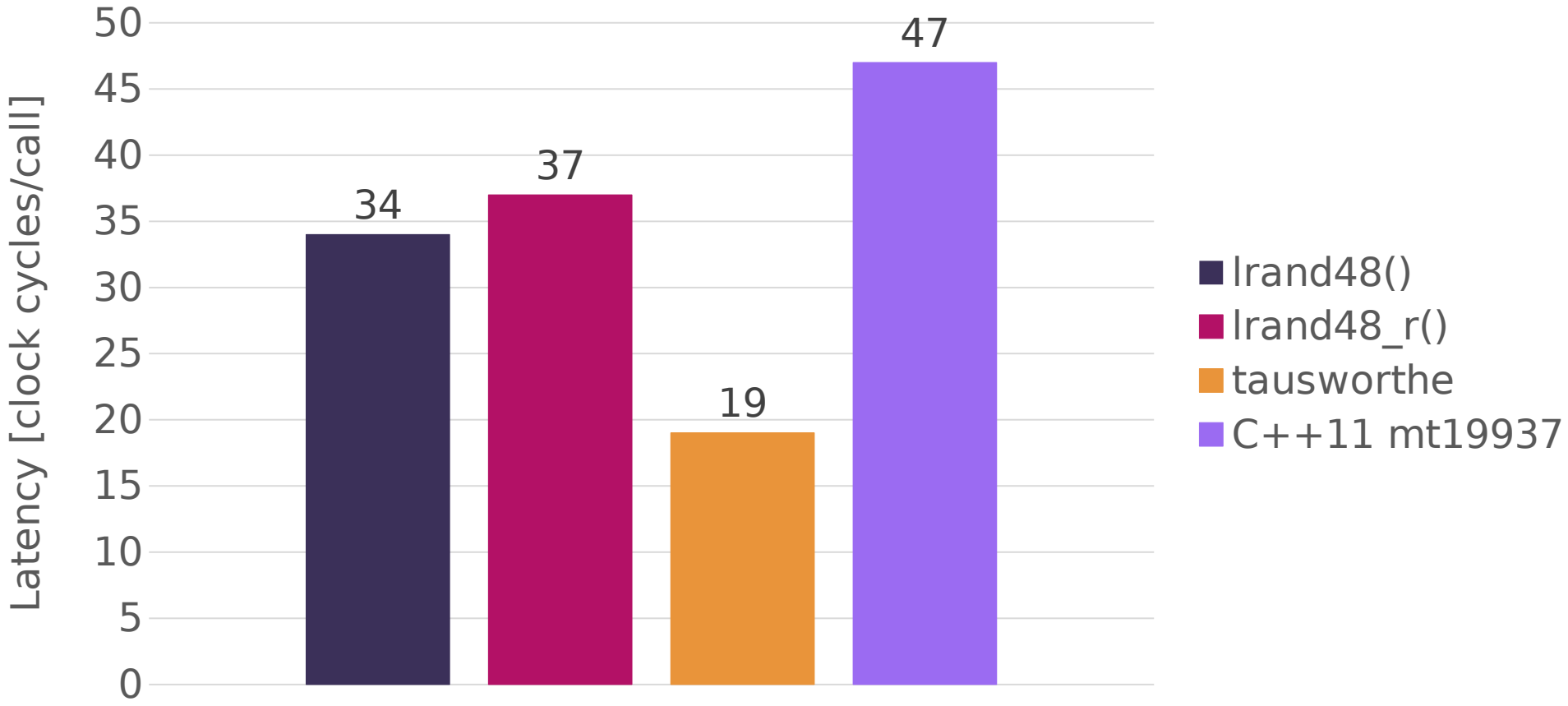
- DPDK-native implementation
- Maximally equidistributed combined Tausworthe generator
  - Also known as Linear Feedback Shift Register (LFSR)
  - Well-known and well-analyzed
  - Described in this paper, with this errata paper
  - Allows performant software implementation
  - Five sequences per instance/lcore (40 bytes state)
  - Natively producing a 64-bit number
  - Fairly common, including Linux kernel usage, for similar purposes
    - DPDK code not based on this implementation
- Tausworthe sequences seeded using a LCG

```
struct rte_rand_state {
        uint64_t z1;
        uint64_t z2;
        uint64_t z3;
        uint64_t z4;
        uint64_t z5;
} __rte_cache_aligned;
```

# 19.08: Initial Seeding

- Pre-19.08 relies purely on monotonic CPU wall-time clock (TSC)
- 19.08 improves initial seeding
  - Primary: getentropy() syscall to retrieve “truly” random value
    - Requires Linux libc 2.25+ and kernel 3.17+ or FreeBSD 12
  - 1st Fallback: HW seeding by rdseed x86 instruction
    - x86_64 Broadwell or later
  - 2nd Fallback: TSC register (or equivalent)
    - All systems/hardware

# rte_rand() Performance

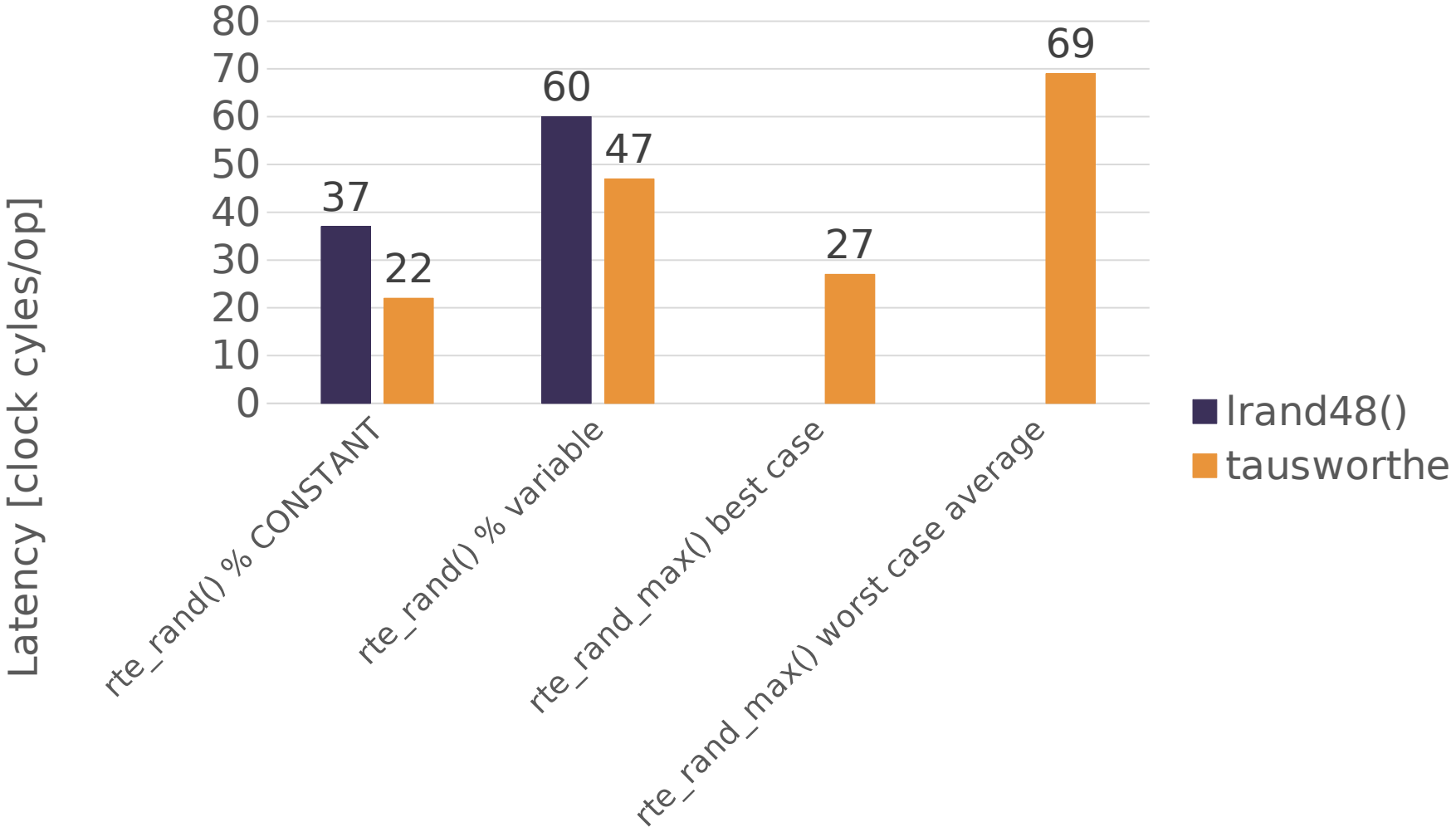



System: Skylake @ 2,9 GHz

# 19.08: Bounded PRNG

- rte_rand() % UPPER_BOUND -> range [0 - UPPER_BOUND-1]
  - Constant power-of-2 UPPER_BOUND (i.e. 2^N): Very fast and uniform
  - Constant non-power-of-2: Fast, but biased (reduced uniformity)
  - Variable UPPER_BOUND: Slower, often biased
  - Bias only significant for large UPPER_BOUNDs
- rte_rand_max() produces *unbiased* pseudo-random numbers with an upper bound

# Bounded PRNG




# Questions?

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