

Contiki: A Lightweight and Flexible Operating
System for Tiny Networked Sensors

Protothreads: Simplifying Event-Driven
Programming of Memory-Constrained Embedded
Systems

Contiki

The Open Source OS for the Internet of Things

SensorWare

Mantis

Nemesis



Fibers

Exokernel

Contiki

Open source operating system for the Internet of
Things

Contiki

Event Driven Kernel

Requires State Machines

Problems with Long Running Computations

Preemptive Multithreading on Top of Event
Driven Kernel

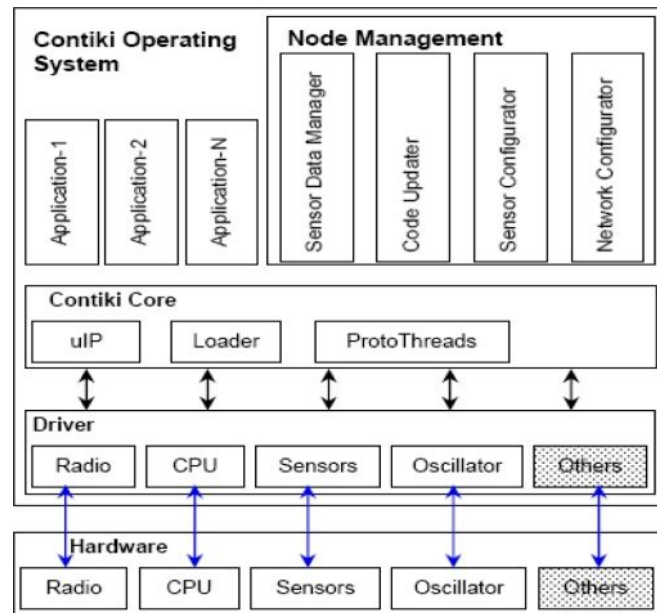
Implemented Using Protothreads

Loadable Programs, Services

Core vs Programs

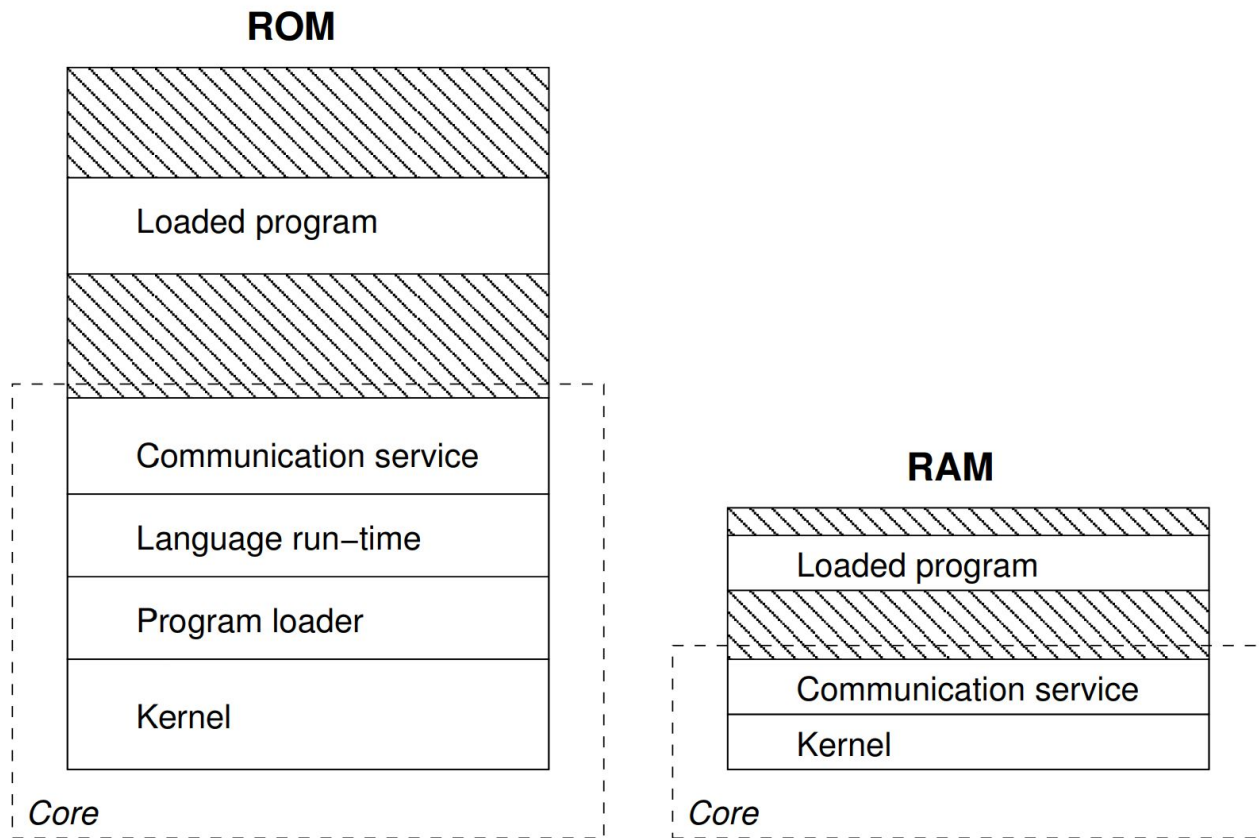
Power Save Mode

Uses Event Queue

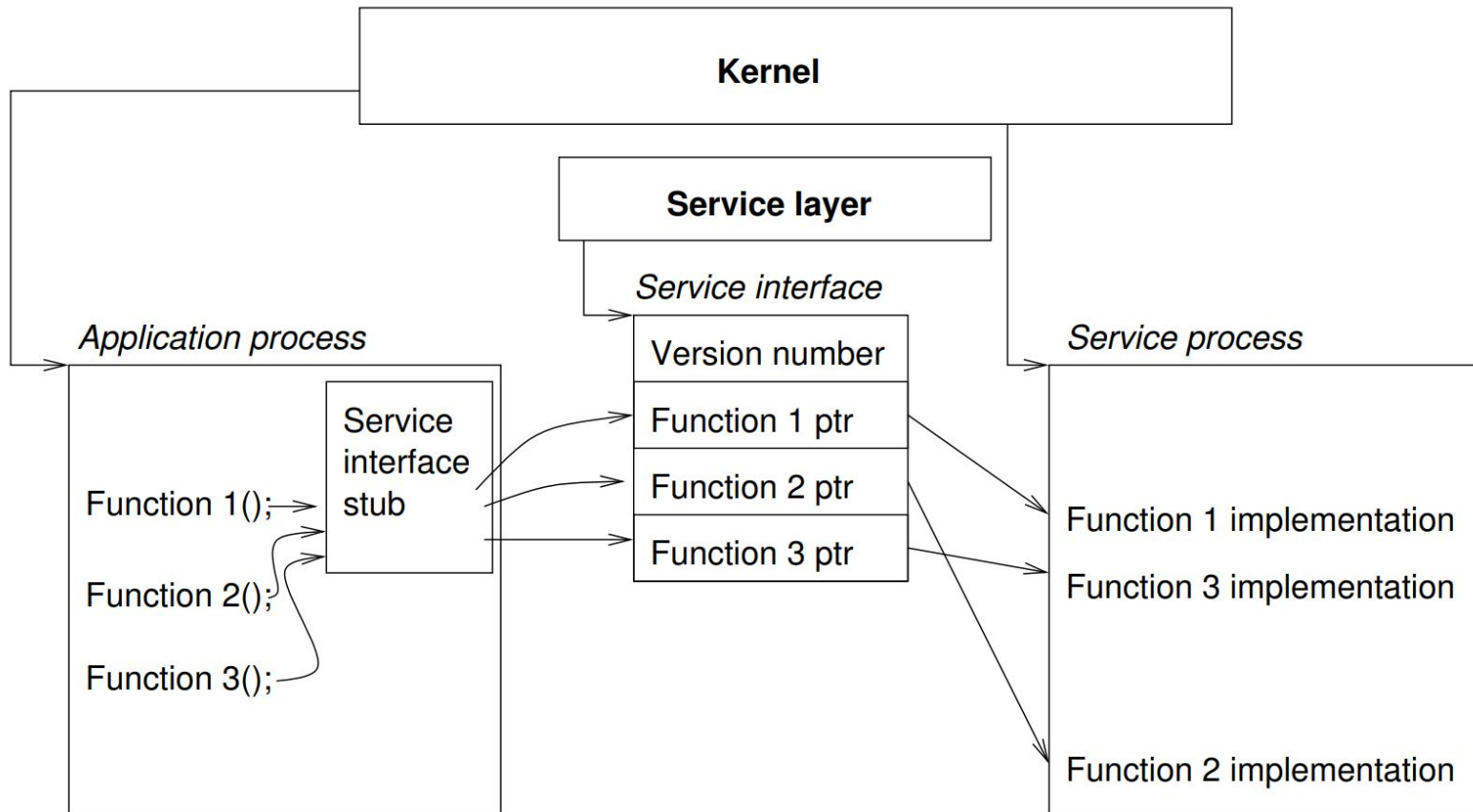


https://openi.nlm.nih.gov/detailedresult.php?img=PMC3231431_sensors-11-05900f3&req=4

System Partitioning Overview



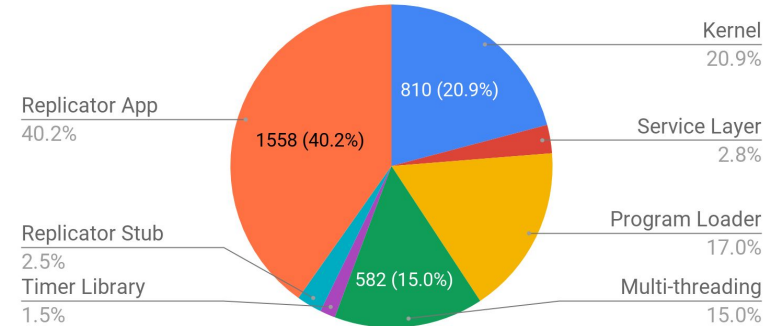
Service Overview



Contiki RAM Allocation

Module	Code size (AVR)	Code size (MSP430)	RAM usage
Kernel	1044	810	$10 + 4e + 2p$
Service layer	128	110	0
Program loader	-	658	8
Multi-threading	678	582	$8 + s$
Timer library	90	60	0
Replicator stub	182	98	4
Replicator	1752	1558	200
Total	3874	3876	$230 + 4e + 2p + s$

Contiki MSP430 Compiled



Process Count (p) | Event Queue Size (e) | Thread Stack Size (s)

Protothreads

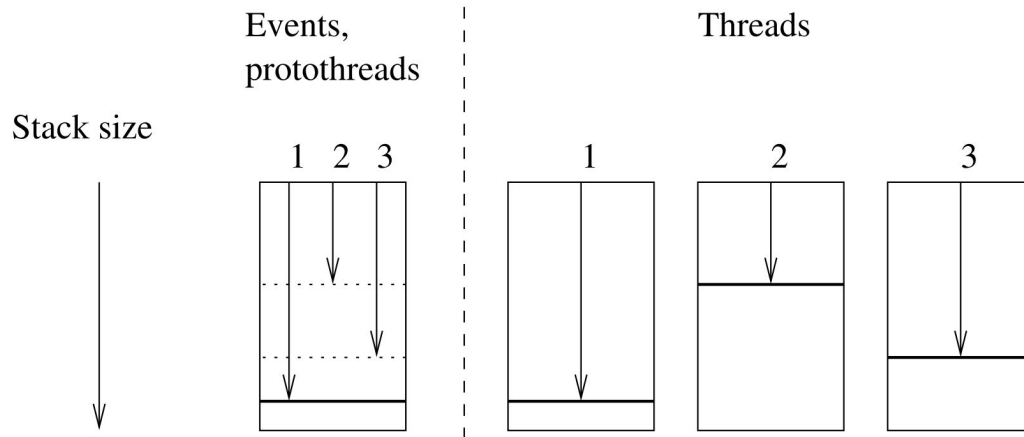
Simplifying Event-Driven Programming of
Memory-Constrained Embedded Systems

Protothreads

Simplifies Implementation of Control-Flow State Machines

Allows Sequential Execution Without the Overhead of Allocating Multiple Stacks
Evaluation

State Count, Transition Count, Lines of Code of Reimplemented Functions



Code Complexity Reduction and Overhead

Program	States, before	States, after	Transitions, before	Transitions, after	Lines of code, before	Lines of code, after	Reduction, percentage
XNP	25	-	20	-	222	152	32%
TinyDB	23	-	24	-	374	285	24%
Mantis CC1000 driver	15	-	19	-	164	127	23%
SOS CC1000 driver	26	9	32	14	413	348	16%
Contiki TR1001 driver	12	3	32	3	152	77	49%
uIP SMTP client	10	-	10	-	223	122	45%
Contiki code propagation	6	4	11	3	204	144	29%

Table 1. The number of explicit states, explicit state transitions, and lines of code before and after rewriting with protothreads.

Program	Code size, before (bytes)	Code size, after (bytes)	Increase
XNP	931	1051	13%
TinyDB DBBufferC	2361	2663	13%
Mantis CC1000	994	1170	18%
SOS CC1000	1912	2165	13%
Contiki TR1001	823	836	2%
uIP SMTP	1106	1901	72%
Contiki code prop.	1848	1426	-23%

Table 2. Code size before and after rewriting with protothreads.

	State machine	Proto-thread	Thread
Contiki TR1001 driver	1	2	18
Contiki code propagation	1	2	34

Table 3. Memory overhead in bytes for the Contiki TR1001 driver and the Contiki code propagation on the MSP430, implemented with a state machine, a protothread, and a thread.

	State machine	Proto-thread	Yielding protothread
MSP430	9	12	17
AVR	23	34	45

Table 4. Machine code instructions overhead for a state machine, a protothread, and a yielding protothread.