임베디드 소프트웨어 통합개발환경 : Esto

2006. 2. 13.

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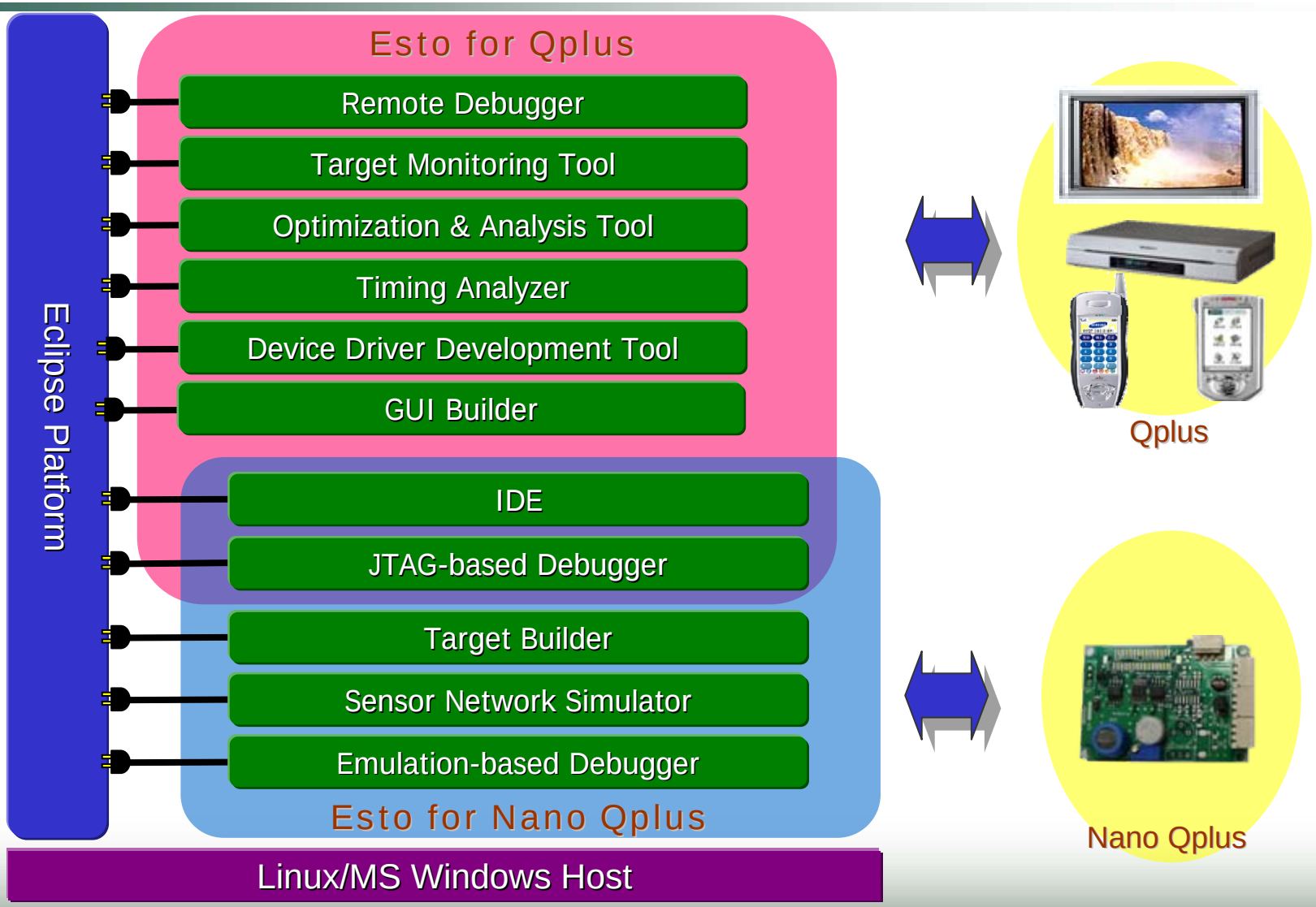
Esto


Eclipse Platform
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Optimization & Analysis Tool
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Esto for Nano Qplus
Linux/MS Windows Host
Qplus
Nano Qplus

Esto Features

- Accelerate Developer Productivity of Qplus and Nano Qplus based Embedded Software
- Based on Eclipse

- Esto for Qplus
  - Target
    - X86, ARM, Xscale, MIPS, PowerPC
  - Project based source editing, cross compilation, remote execution
  - Remote debugging for application and kernel module
  - Non-stop debugging
  - JTAG-based firmware debugging
  - Monitoring various target resources (CPU, memory, etc.)
  - Power, performance analysis and source code optimization
  - Integrated and seamless analysis on schedulability and WCET (Worst Case Execution Time)

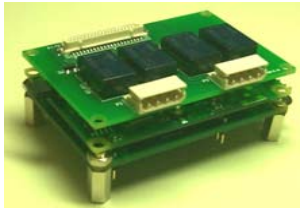
- Esto for Nano Qplus (Nano Esto)
  - Target
    - AVR
  - Project based source editing, cross compilation, remote execution
  - Automatic loading of executable image to target system
  - JTAG-based sensor node debugging
  - Emulator-based debugging
  - GUI-based sensor network simulation
  - Simulation-based power analysis for sensor network
  - Fast and convenient kernel configuration and build

Qplus

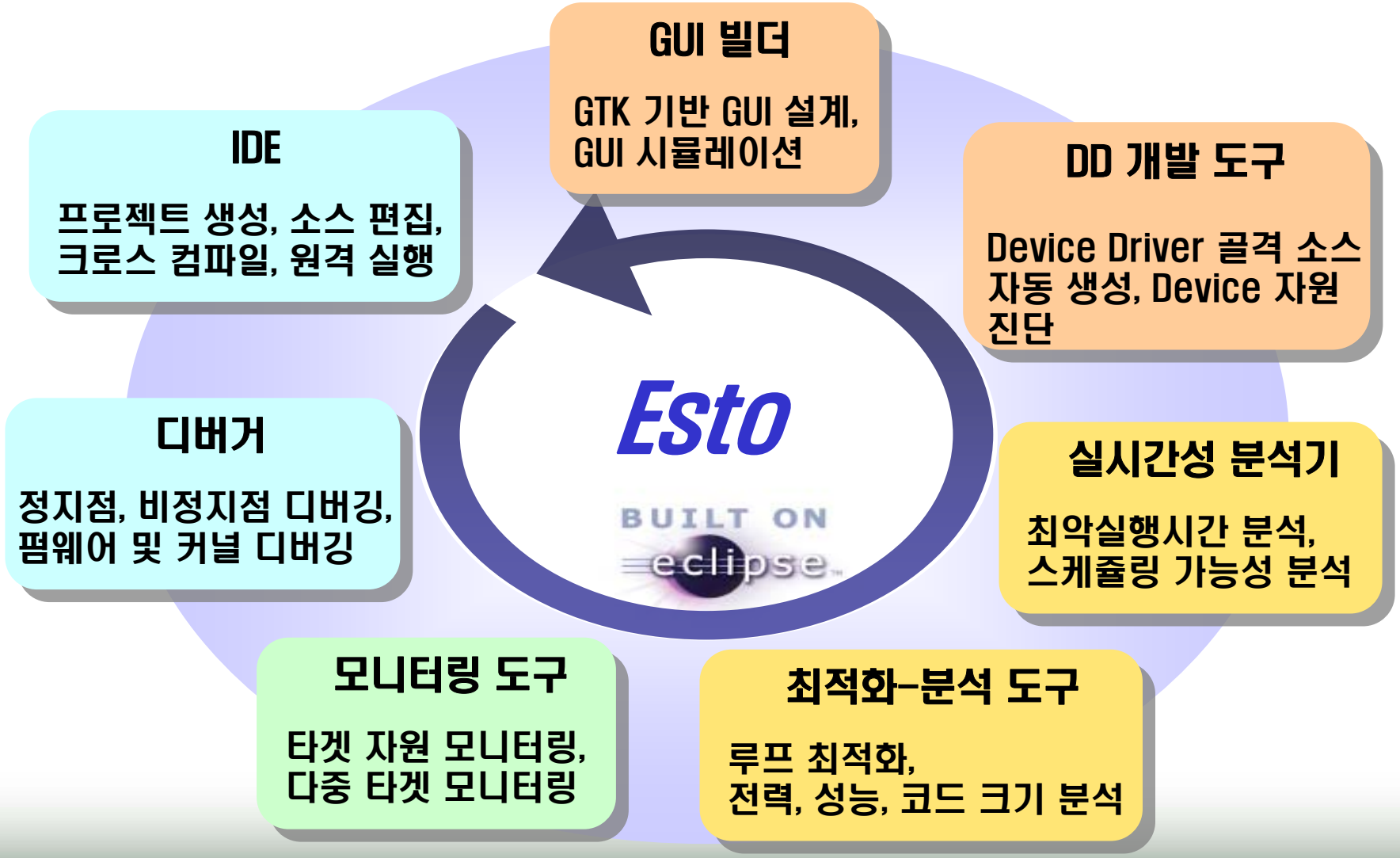
- Kernel Features
  - Real-Time
    - Preemptible kernel
    - POSIX high resolution timer
  - Power Management
    - ACPI
    - Support safe turn off functionality
  - Fast Boot
    - PRESET LPJ (Loops Per Jiffy)
      Save 350 msec on EPIA-M board
  - TV OUT kernel frame buffer
- Other Features
  - TinyX
  - Matchbox window manager
  - Gtk-2.6
  - GPE based application management environment
  - Web browser : minimo firefox-1.0.6
  - Media player : mplayer-1.0
- Target Builder
  - Embedded system configuration toolkit
  - Easy build up target root file system
  - Kconfig based integrated configuration system
    - Linux kernel 2.6.x
    - Automated dependency checking
  - RPM based packaging system
  - Library optimization
  - Fine-grain control of system
    - File-list, compile options, etc.
  - Support various root filesystem types
    - ext2, ext3, ramdisk image, jffs2, etc.
  - Support various deployment methods
    - CD installer, USB memory stick installer, serial installer, NFS, etc.
  - Based on Eclipse platform
  - Licensed by GPL
  - Include CELF patches currently 2.6.9

Nano Qplus

- Small-sized, Distributed, Real-time, and Smart OS
- For Sensor Networks under Ubiquitous Environment
  - E.g., medical services, environmental systems, disaster prevention, digital home, national defense systems, etc.
- Main Features
  - Reconfigurable, scalable OS
    - Can be optimized for various sensors and actuators
    - Supports better S/W architecture than TinyOS of UC Berkeley
  - Various scheduling policies
    - FIFO, Preemption, LEDF, etc.
  - Various wireless communications
    - RF, ZigBee, Bluetooth, etc.
  - Same API sets as Qplus

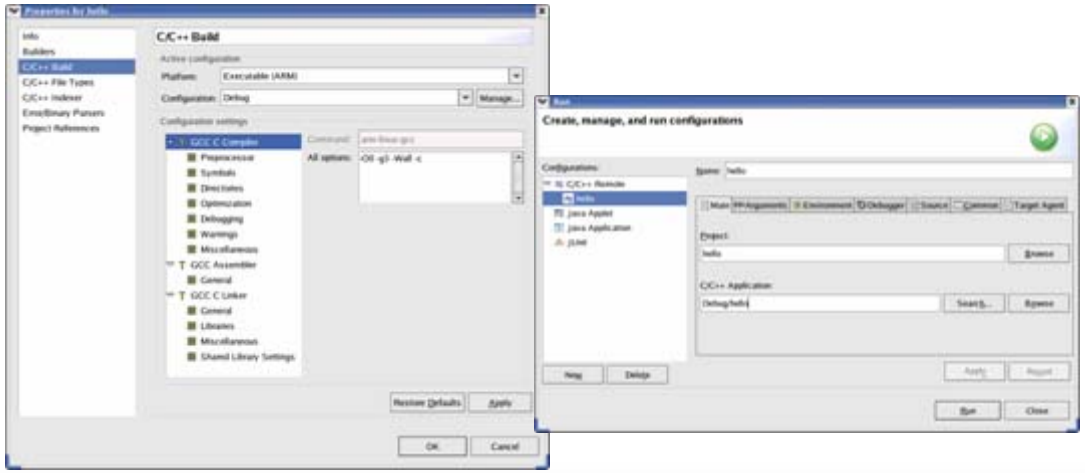


Esto for Qplus



IDE

- Project Management
  - Creation, configuration, and building
  - Makefile management
  - Qplus package import/export
- Development
  - Source code editing facilities
    - Syntax highlighting, automatic formatting, class browsing, etc.

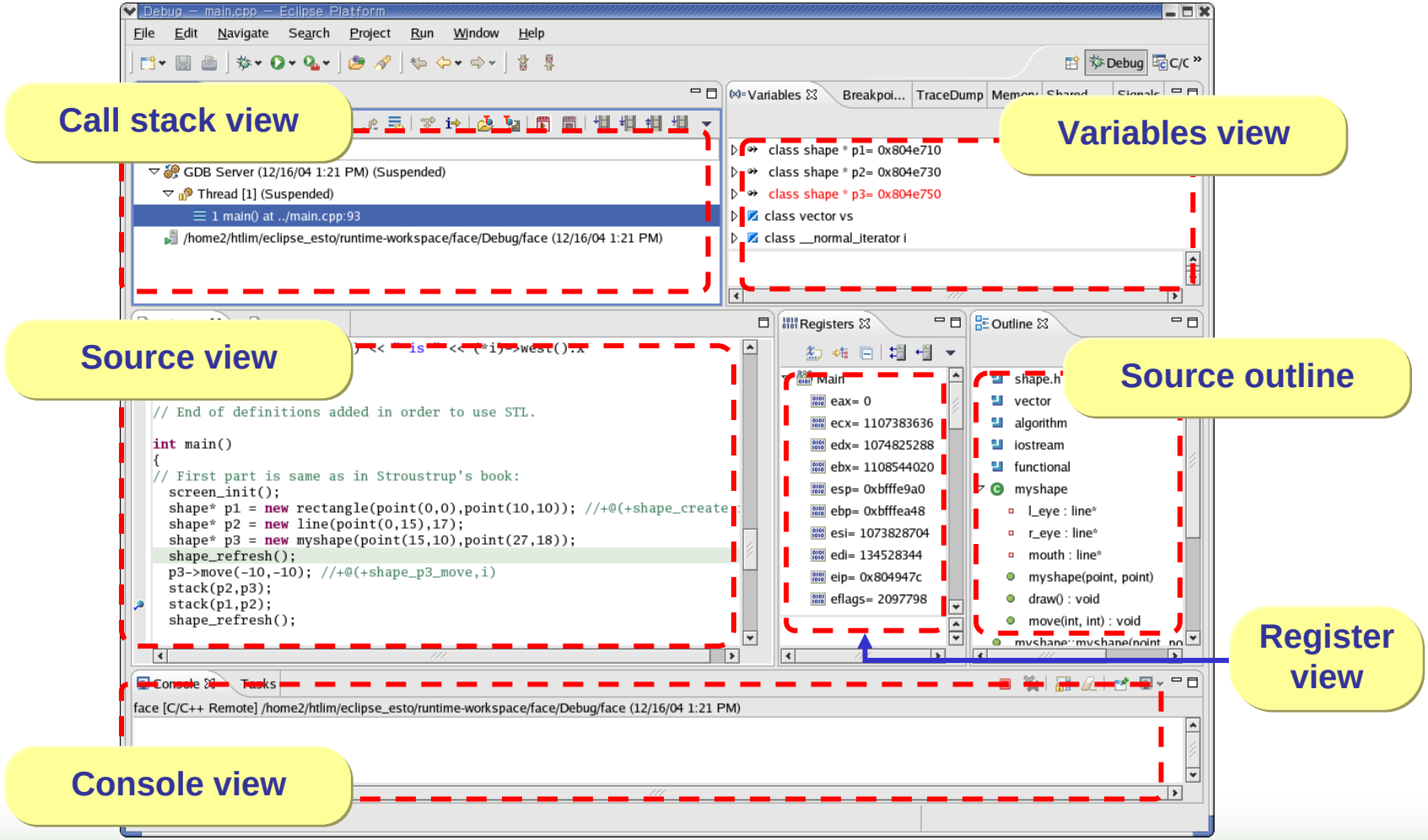


Project Build & Remote Execution Configuration

Debugger

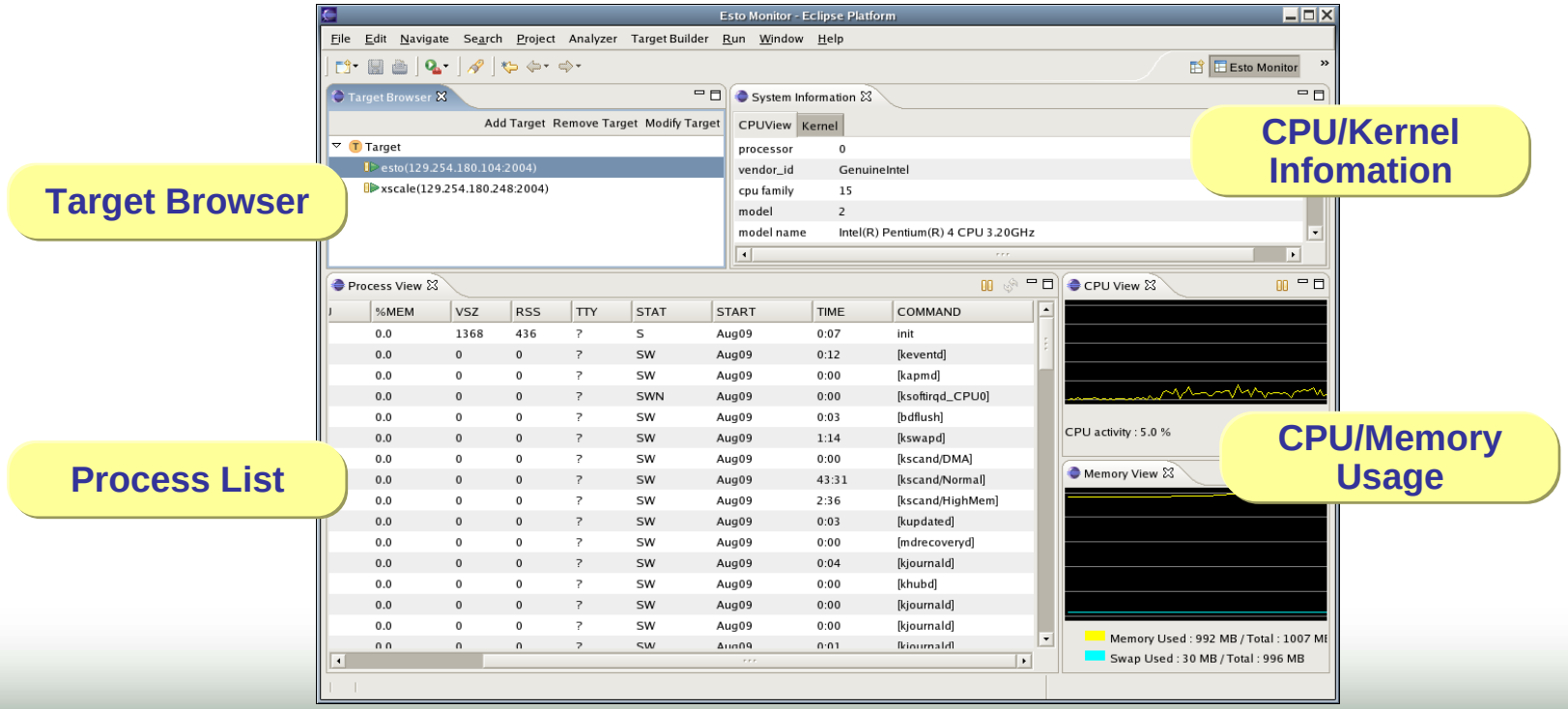
- Remote Debugger
  - Remote debugging starts with just one button click
  - Nonstop-debugging with tracepoint and replay
    - For time-sensitive applications
- JTAG-based Debugger
  - A cost-effective way to debug applications on a target system
    - Needs only a cheap JTAG adaptor
  - Supports full C source level debugging
  - Supports both breakpoint & tracepoint

Snapshot of Debugger



Target Monitoring Tool

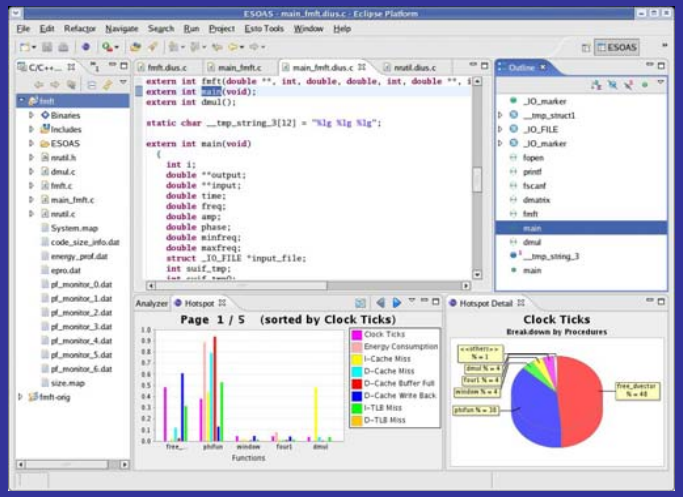
- Concurrent multiple-target monitoring
- Various target resource monitoring
  - CPU, memory, process list, process memory map, kernel module, etc.
- GUI based kernel event trace
- Remote tracing of system call and library function



Optimization and Analysis Tool

- Optimizing Application
  - By using loop transformation such as loop distribution, loop interchange, loop unrolling, and scalarization
- Analyzing Power of Embedded Application
  - Together with performance and code size
- GUI-Based Integration of Optimizing and Analyzing

Multi-meter & Target System



Optimization & Analysis Tool

Timing Analyzer

- Static timing analyzer for C/C++ based real-time application
  - Analyzes WCET (Worst-Case Execution Time)
    - Considering XScale micro-architecture's characteristics such as pipeline & cache.
    - WCET analysis for OS components, such as a scheduler and interrupt service routines, based kernel source code
  - Analyzes Schedulability based on RMA (Rate Monotonic Analysis)

TMO	Type	Name	Period	WCET	Blocking	Jitter	Deadline	Response Time	Schedulability
OpticalSensorTMO	SpM	SenseObjectSpM	500000	2309	2309	2000	30000	18274	schedulable
OpticalSensorTMO	SvM	CheckDetectionSvM	450000	4109	4109	0	50000	8228	schedulable
DoorTMO2	SpM	SenseDoorSpM1	500000	2409	2409	2000	15000	20785	unschedulable
DoorTMO2	SpM	SenseDoorSpM2	500000	2409	2409	2000	15000	23196	unschedulable
DoorTMO2	SpM	MoveDoorSpM	450000	7533	7533	2000	400000	21187	schedulable

Analyzed WCET

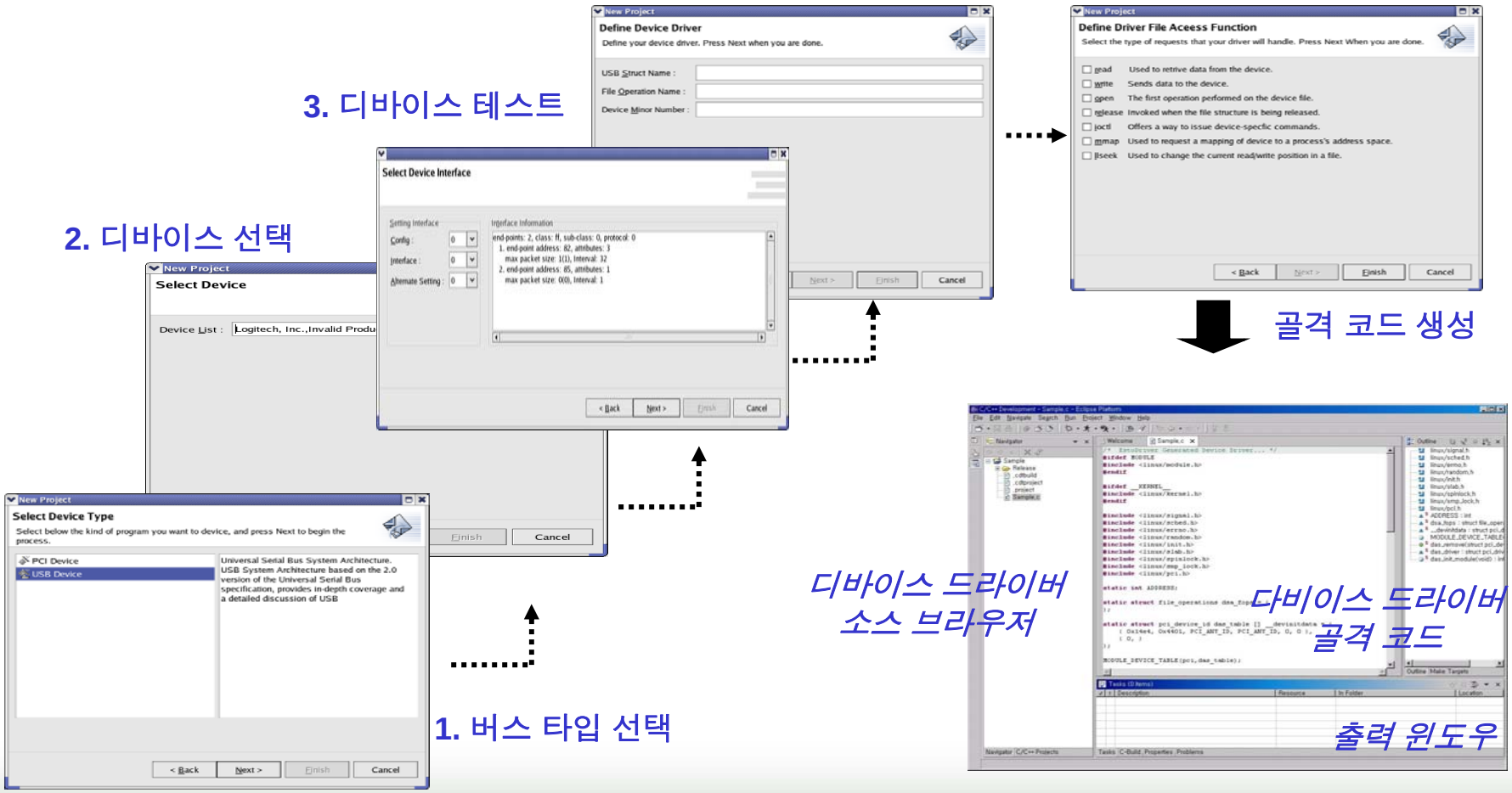
Final results of schedulability analysis

디바이스 드라이버 개발 도구

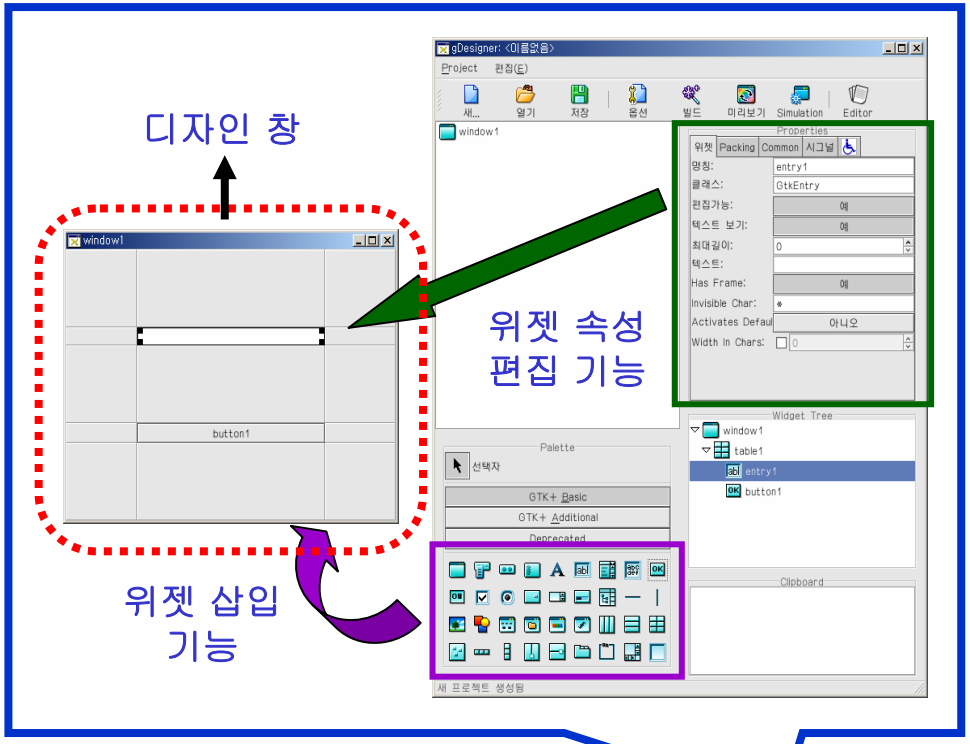
❖ 특징

- 드라이버 프로젝트 위저드
  - 디바이스 드라이버의 골격 코드 생성을 안내해줌
  - 드라이버 타입(문자, 블록, 네트웍)과 디바이스 타입(PCI, USB, IEEE1394, 디바이스 없는 경우)을 고려한 골격 코드 생성
- 디바이스 테스트 위저드
  - 즉시 하드웨어에 접근하고 진단 가능
  - PCI, USB, IEEE1394 디바이스 리소스 테스트 제공
- 원격 개발 지원
  - 타겟에 디바이스 드라이버 다운로드
  - 디바이스 드라이버를 타겟 커널에 삽입/제거 가능
  - 커널 메시지 로깅 뷰어
  - 커널 API 원격 실행기

디바이스 드라이버 개발 도구



GUI 빌더 (gDesigner)

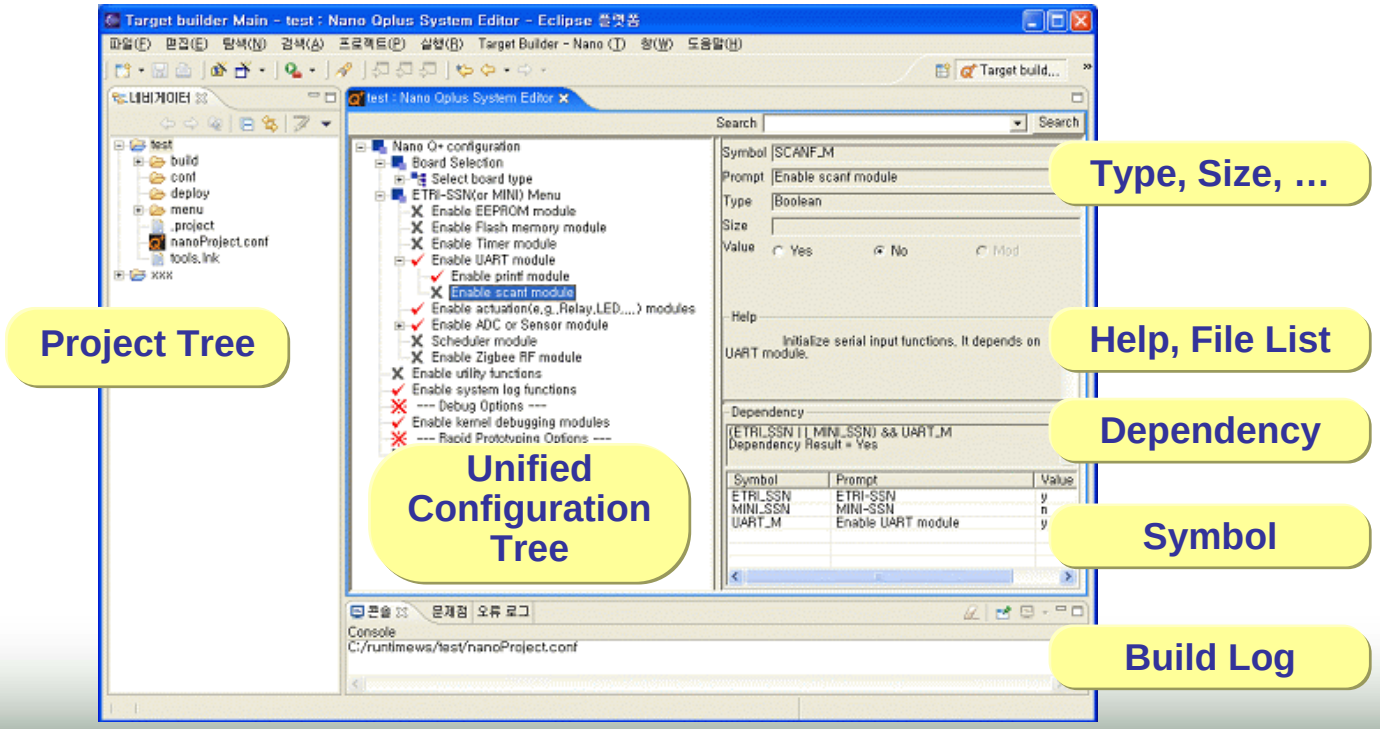


Desktop PC / Notebook PC

Esto for Nano Qplus (Nano Esto)

Target Builder for Nano Qplus

- Unified Configuration System
  - Configures kernel, packages and target specific options altogether
  - Dependencies are checked automatically
- Easy and Fast Kernel Build System
  - Just load provided pre-configurations for a certain BSP
  - Point & Click selection of each module with user friendly GUI



IDE

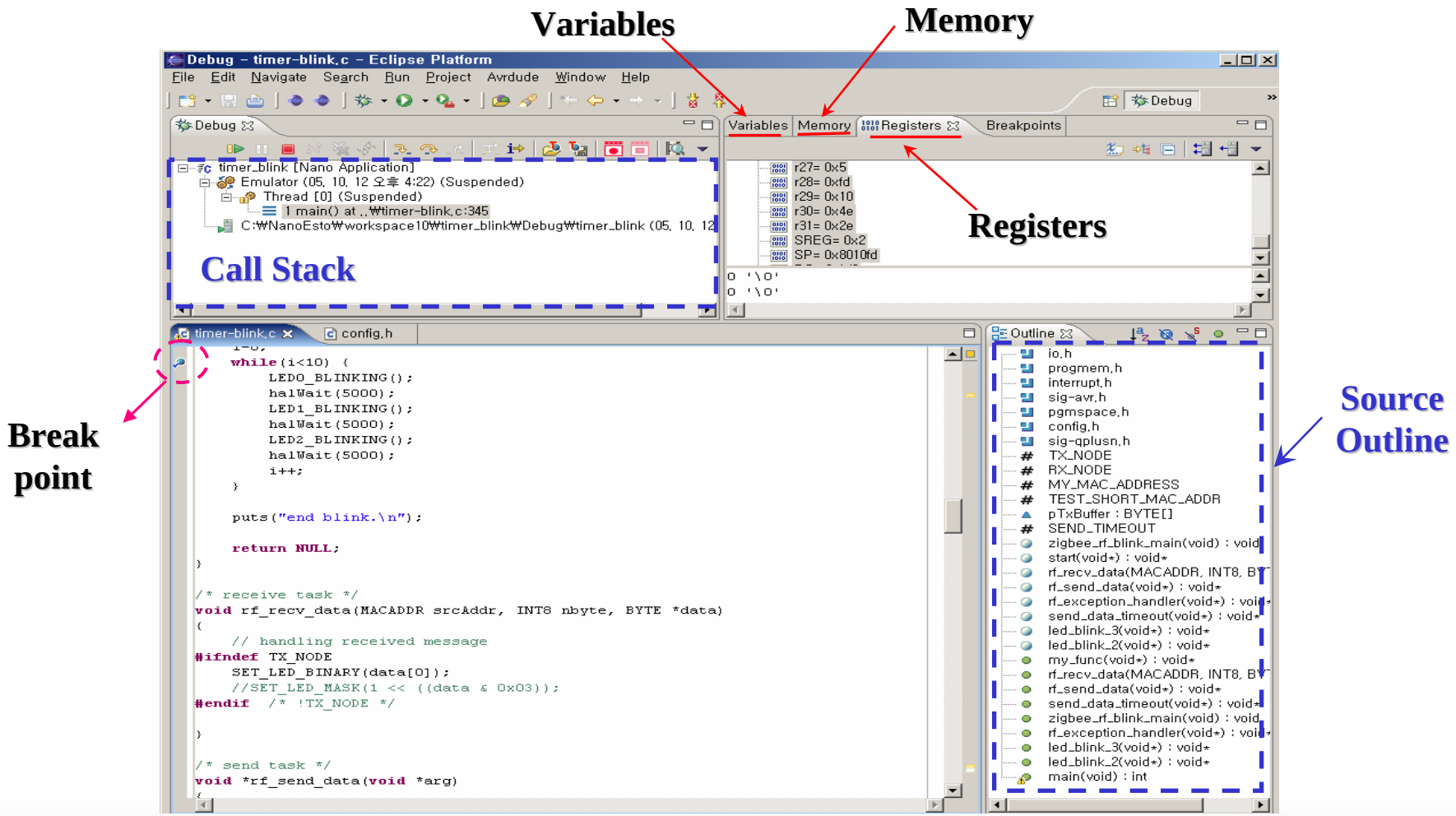
- C source editor
  - Offers highlighting syntax, auto indentation, and browsing facilities for showing variables and functions
- Project Manager
  - Provides project creation, configuration and building
- Executable Image Downloader (Fusing Tool)
  - Downloads and runs applications on a target system with just a click
- Rapid prototyper
  - Creates skeleton code based on user's kernel module selection
  - Users do not have to develop applications from scratch

Debugger

- Emulator based approach
  - checks stability before downloading an executable image
  - Supports debugging without a target system

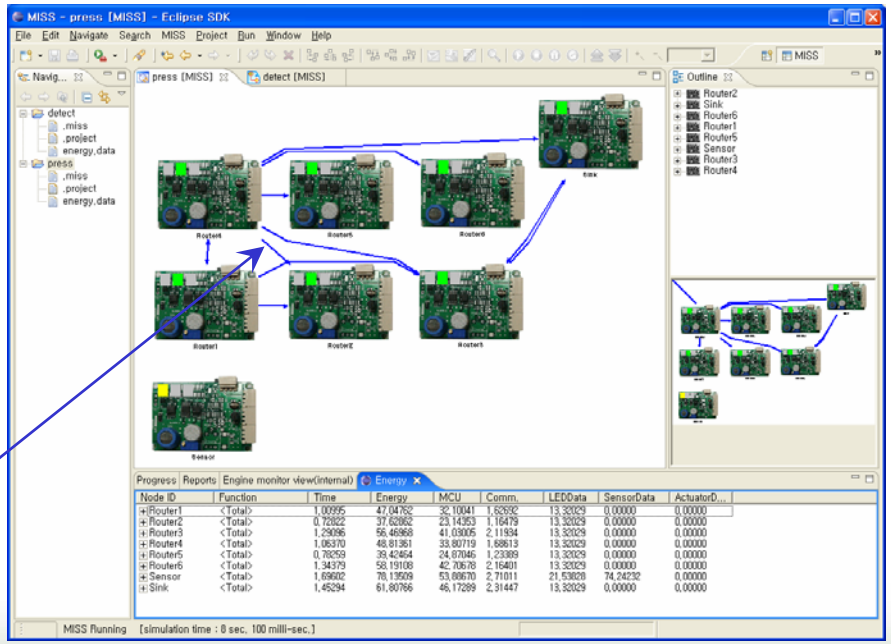
- JTAG based approach
  - A cost-effective way to debug applications on a target system
    - Needs only a cheap JTAG adaptor
  - Supports full C source level debugging

Snapshot of Debugger



Sensor Network Simulator

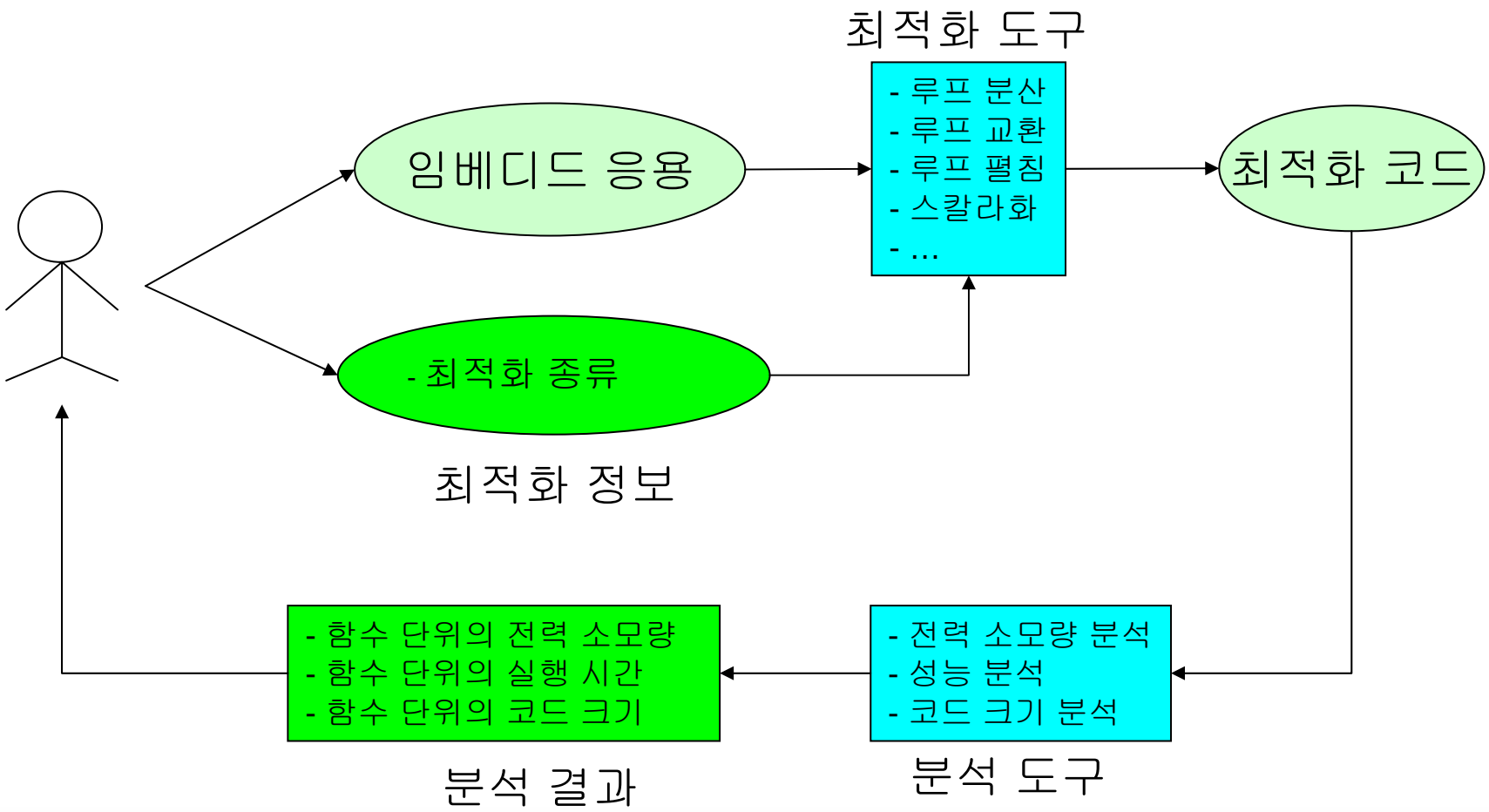
- Scalable network environment simulation
  - Verifies hardware/software design of sensor network
  - Provides a controlled environment for evaluating design alternatives
  - Tests stability of certain network topology
- Precise target sensor node simulation
  - Simulates executable image, which contains machine instructions of ATmega128 core in instruction level
- Accurate power consumption estimation
  - Estimates power consumption of sensor network based on instruction-level power modeling of Atmega128



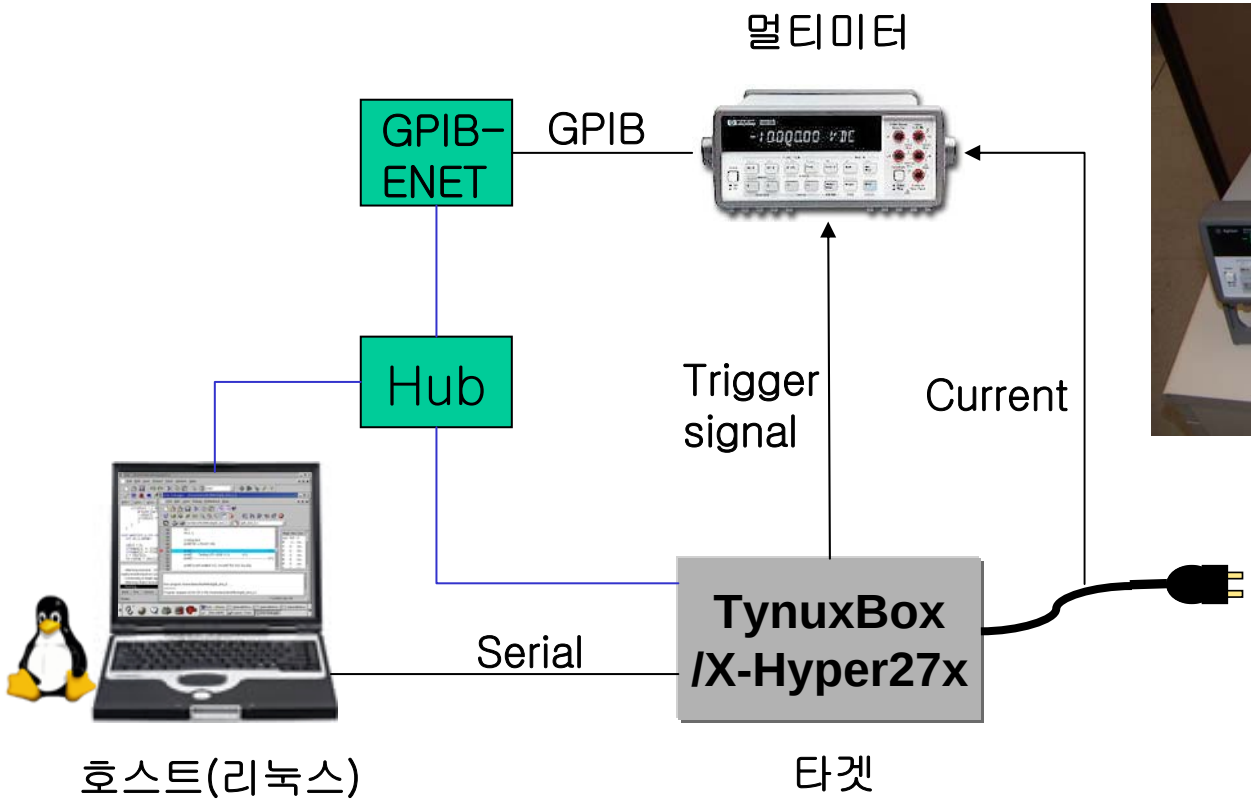
Routing path between two sensor nodes

- 최적화- 분석 도구

최적화-분석 도구 개념도


최적화 도구
- 루프 분산
- 루프 교환
- 루프 펼침
- 스칼라화
- ...
임베디드 응용
최적화 코드
- 최적화 종류
최적화 정보
- 함수 단위의 전력 소모량
- 함수 단위의 실행 시간
- 함수 단위의 코드 크기
- 전력 소모량 분석
- 성능 분석
- 코드 크기 분석
분석 결과
분석 도구

최적화-분석 도구 설치 환경



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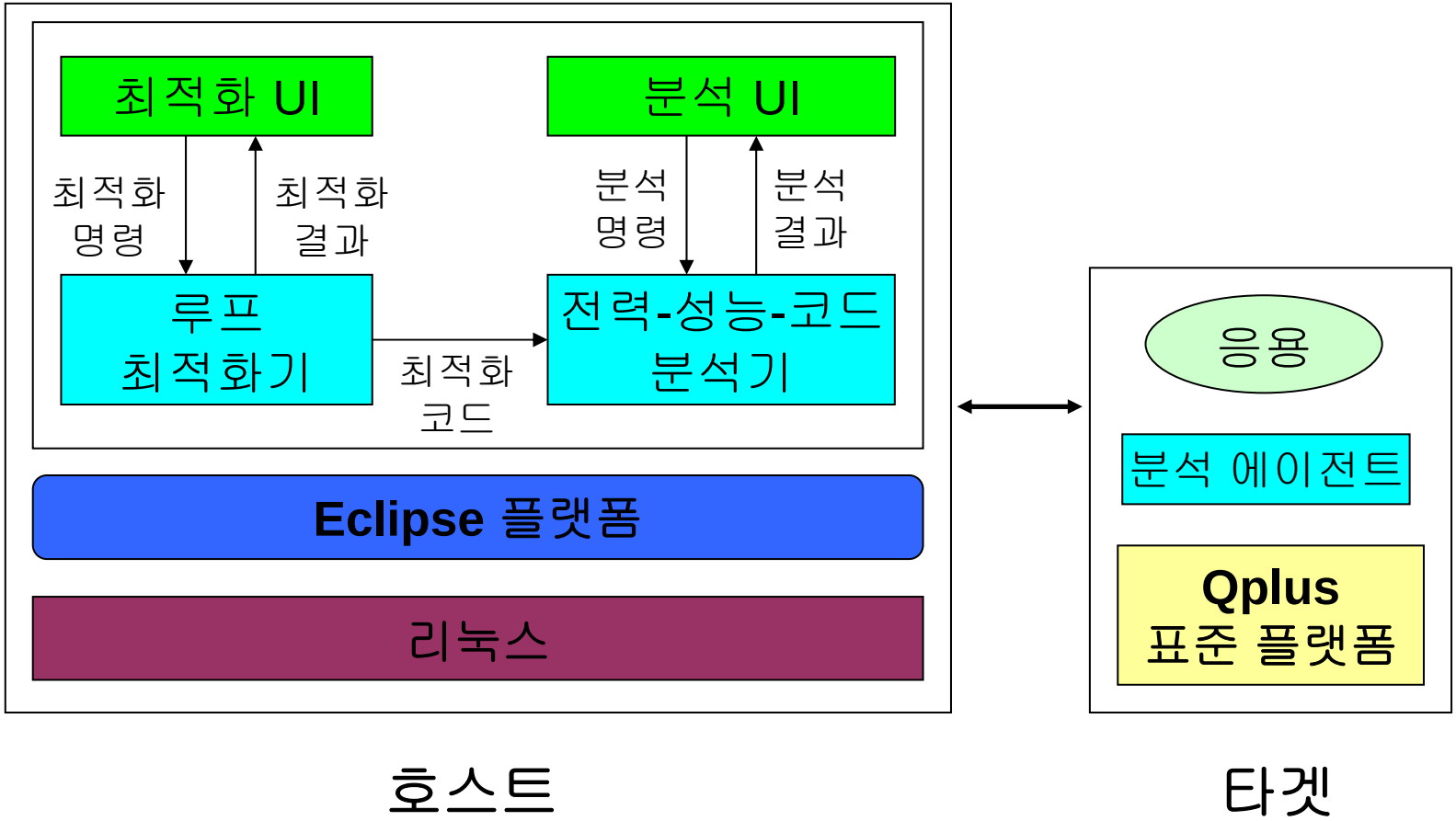
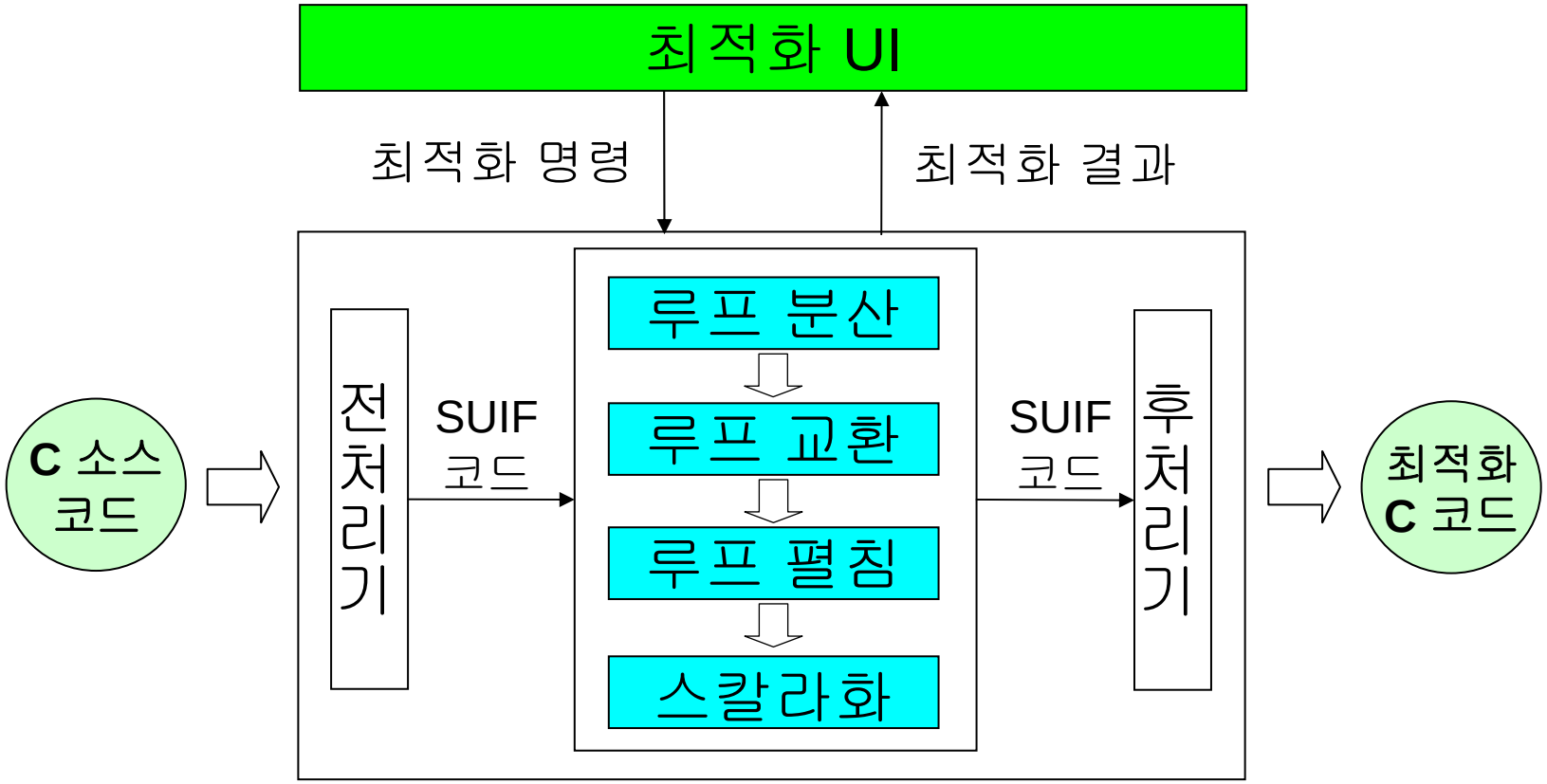
최적화-분석 도구 구조

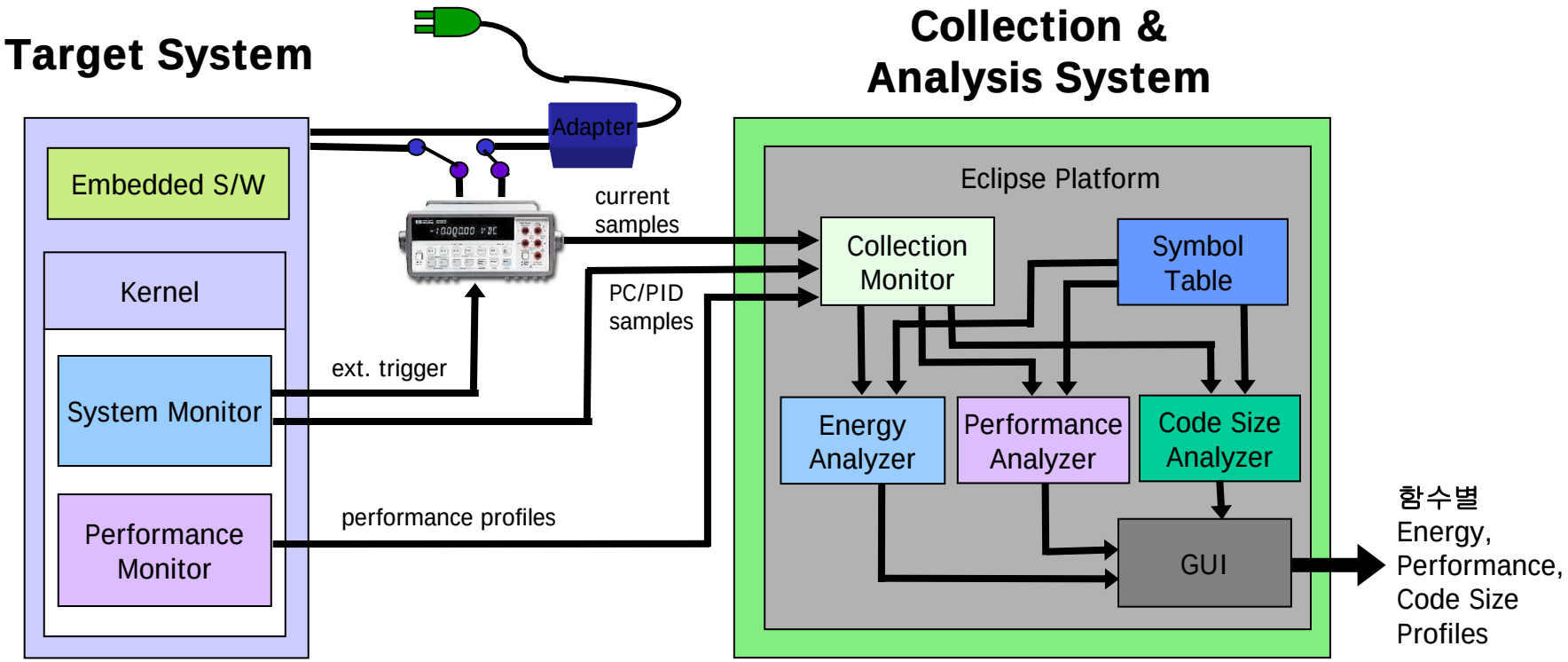

최적화 UI
분석 UI
최적화 명령
최적화 결과
분석 명령
분석 결과
루프 최적화기
최적화 코드
전력-성능-코드 분석기
Eclipse 플랫폼
리눅스
응용
분석 에이전트
Qplus 표준 플랫폼
호스트
타겟

최적화 도구 구조

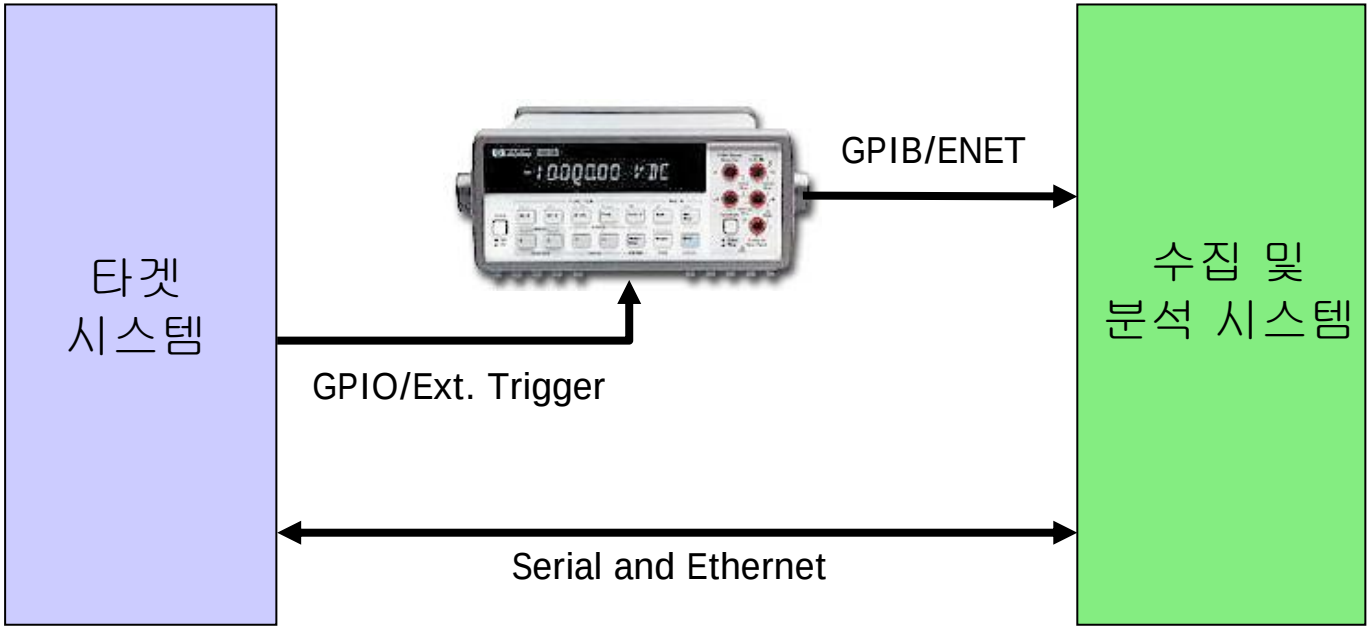


- UI : Eclipse 기반
- 엔진 : Stanford 대학교에서 개발한 SUIF 컴파일러 시스템 기반

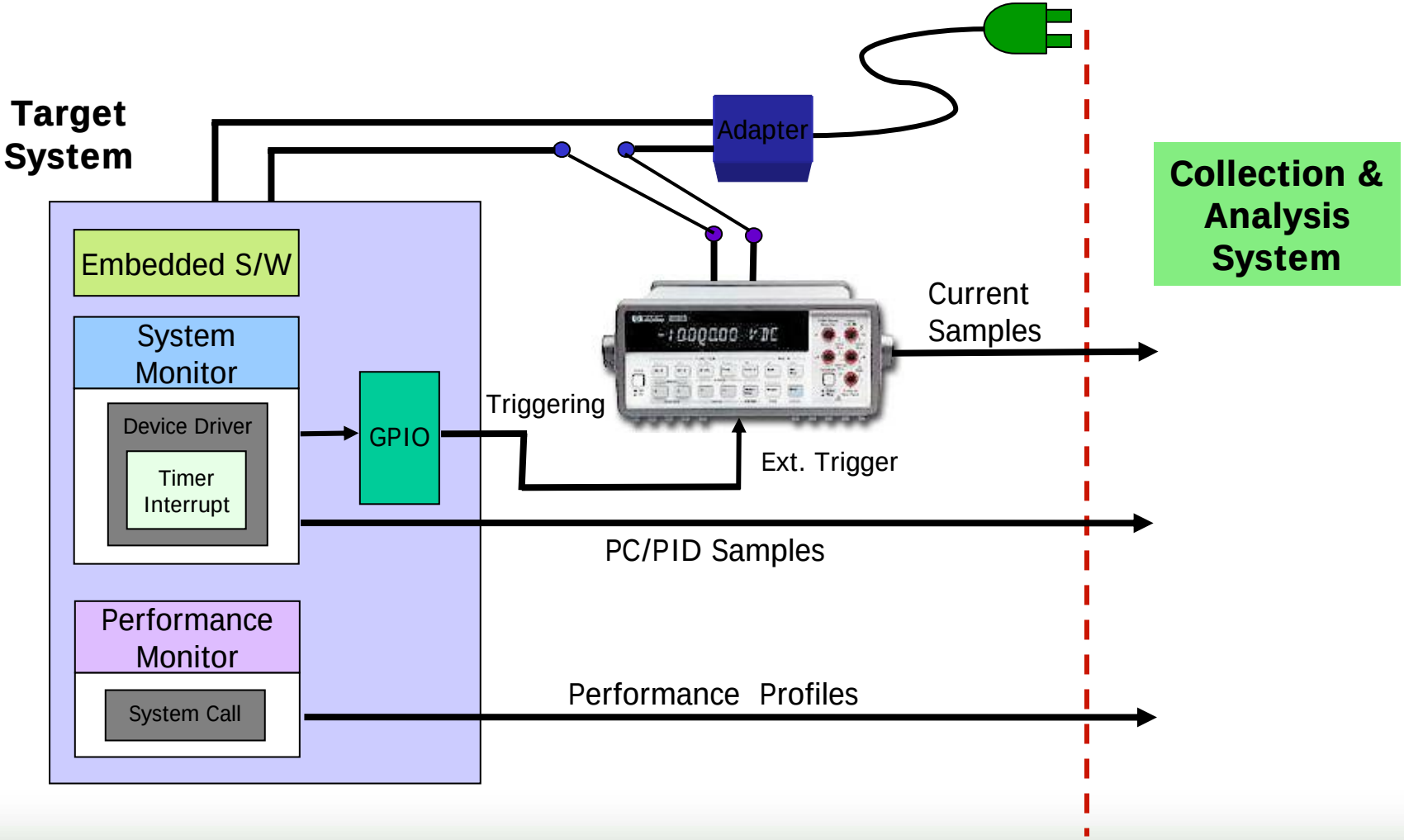
분석 도구 구조


Target System
Embedded S/W
Kernel
System Monitor
Performance Monitor
Adapter
current samples
PC/PID samples
ext. trigger
performance profiles
Collection & Analysis System
Eclipse Platform
Collection Monitor
Symbol Table
Energy Analyzer
Performance Analyzer
Code Size Analyzer
GUI
함수별 Energy, Performance, Code Size Profiles

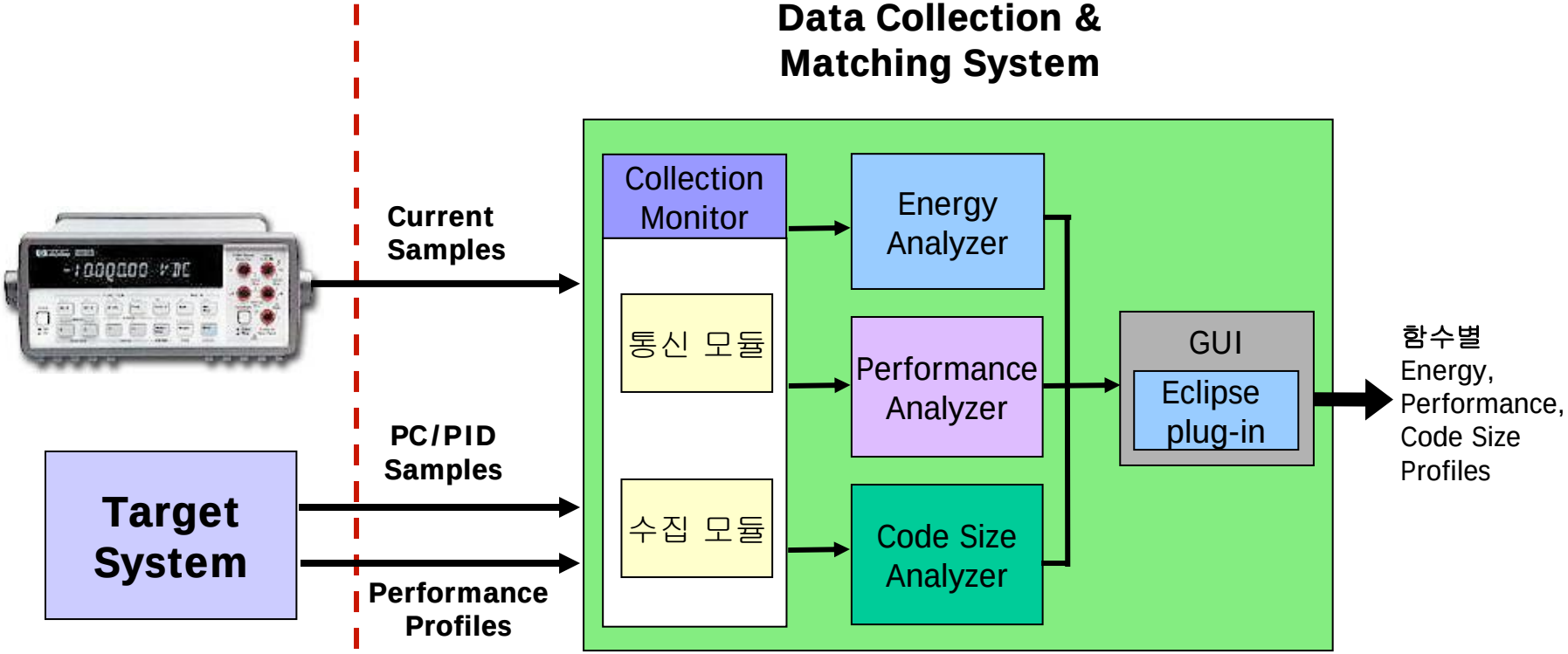
전력 분석 도구 인터페이스



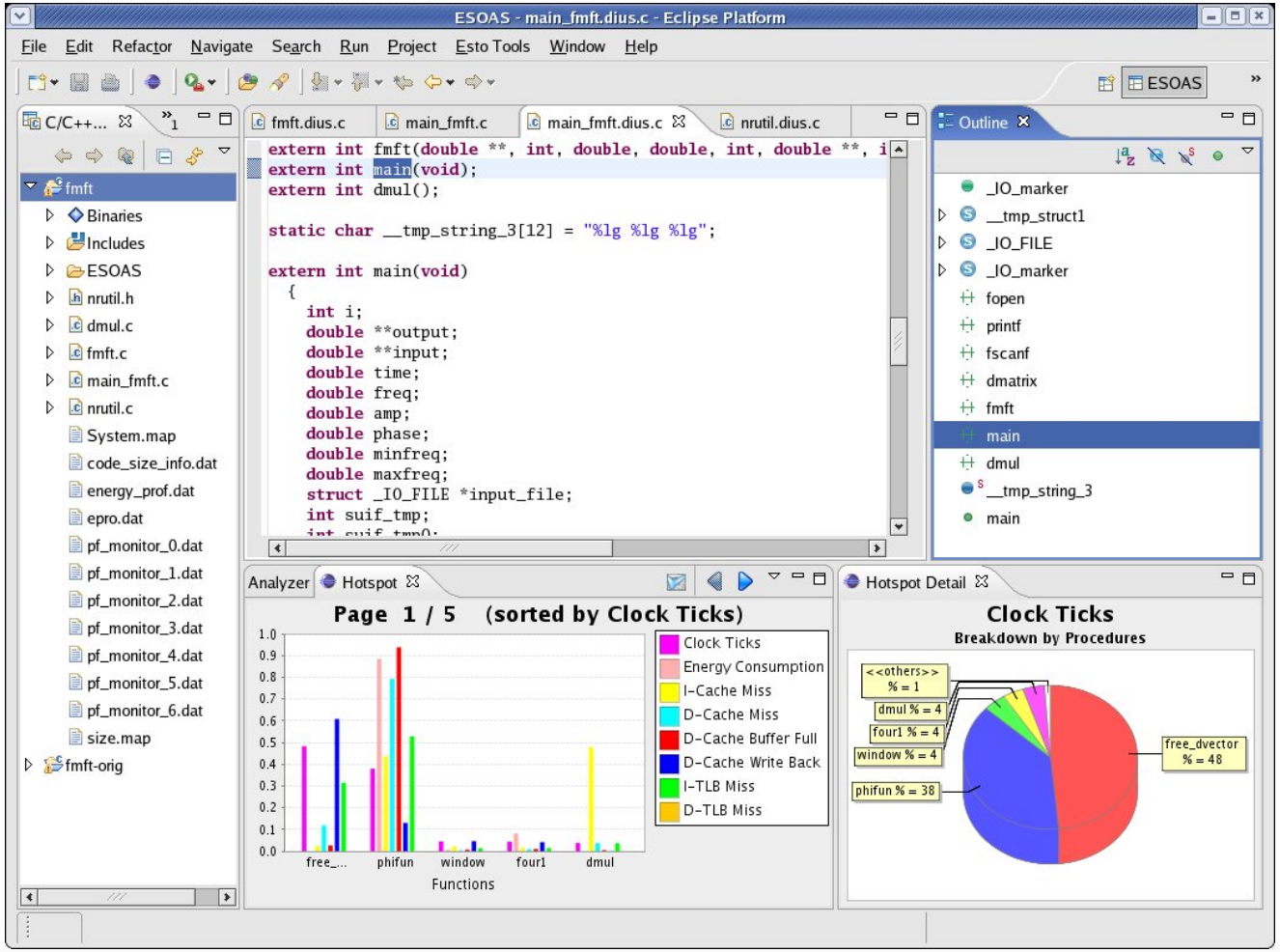
Target System



Collection & Analysis System



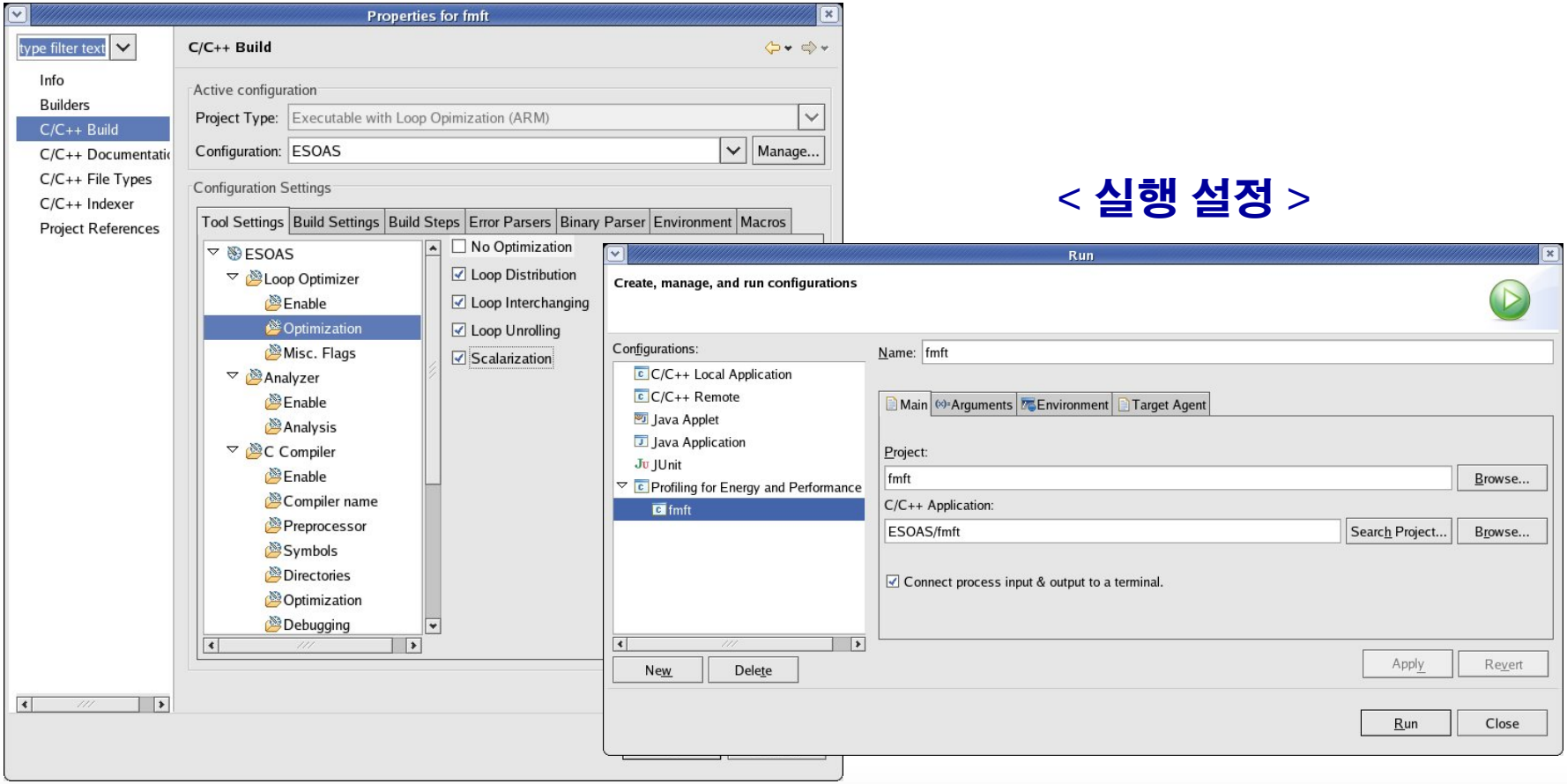
최적화-분석 도구 실행 화면



빌드 & 실행 설정 UI

< 빌드 설정 >

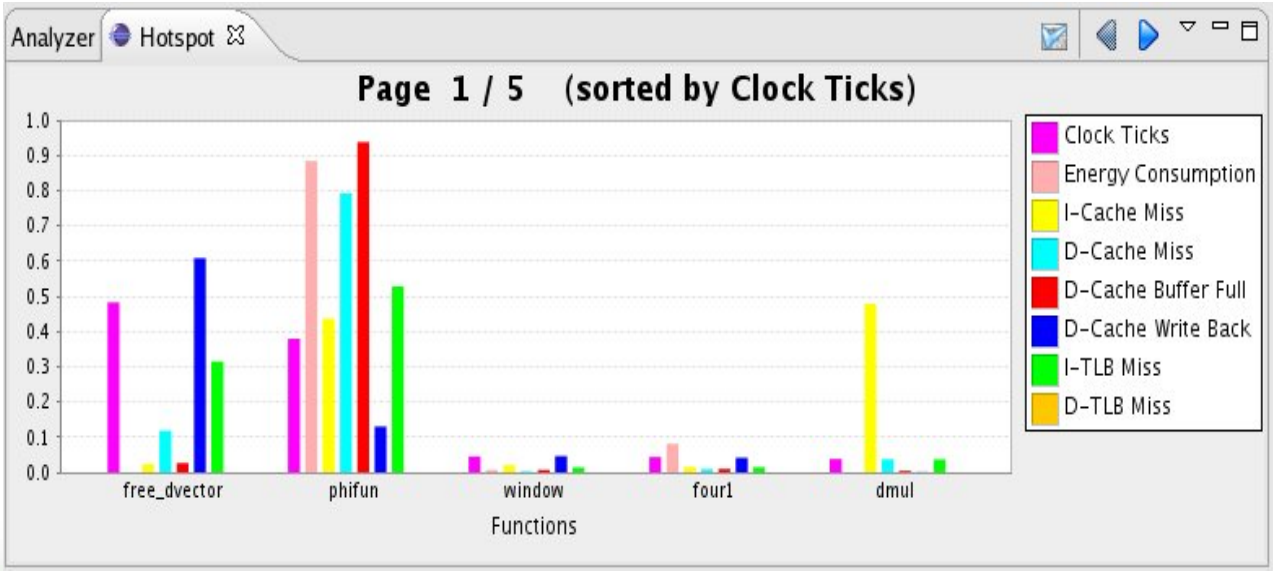
< 실행 설정 >

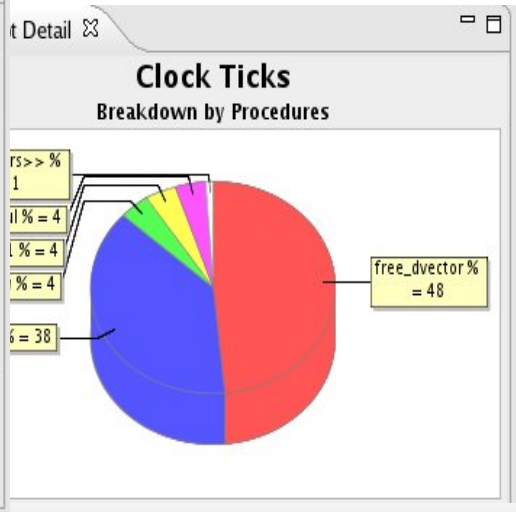


분석 결과

Analyzer | Hotspot

Function	Source	Code Size	Energy Consumption(mJ)	Execution Time(ms)	I-Cache Miss Rate (%)	D-Cache Miss Rate (%)	CPI
amph	fmft.dius.c:1199	184	N/A	0.0479	2.0755	3.7864	9.0302
bracket	fmft.dius.c:956	624	26.5539	2.5315	0.0373	3.2353	1.7084
dindex	fmft.dius.c:1372	880	N/A	0.0302	1.1826	1.9231	4.4686
dmatrix	nrutil.dius.c:136	192	N/A	0.8849	0.9751	18.5611	9.2783
dmul	dmul.dius.c:36	828	N/A	291.2096	0.0066	41.4327	6.2972
dsort	fmft.dius.c:1212	400	N/A	0.0115	2.1818	1.5748	8.3891
dvector	nrutil.dius.c:124	60	N/A	8.3370	0.7064	4.1865	7.4218
fmft	fmft.dius.c:58	10068	52.6951	1.3469	1.0865	46.4155	26.3677
four1	fmft.dius.c:795	1124	300.3645	333.1068	0.0151	0.7114	1.4147
free_dmatr	nrutil.dius.c:198	44	N/A	0.0137	0.6569	0.9202	3.9869

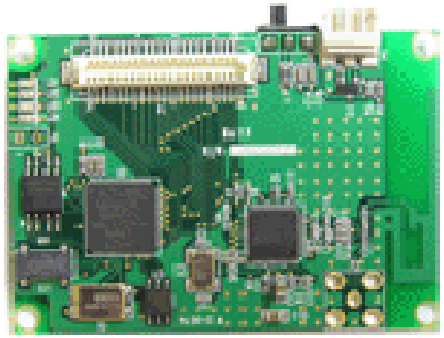




- 센서 네트워크 시뮬레이터

시뮬레이션 환경 (H/W)

- Nano24(옥타컴), MICAz(Crossbow MPR2400)
  - MCU : Atmel ATMega128L
  - RF Transceiver : Chipcon CC2420
    - Frequency : 2.4 GHz ISM band
    - Data Rate : 250 kbps
    - IEEE 802.15.4/Zigbee 지원
    - RF Power : Rx - 19.7mA / Tx - 17.4mA

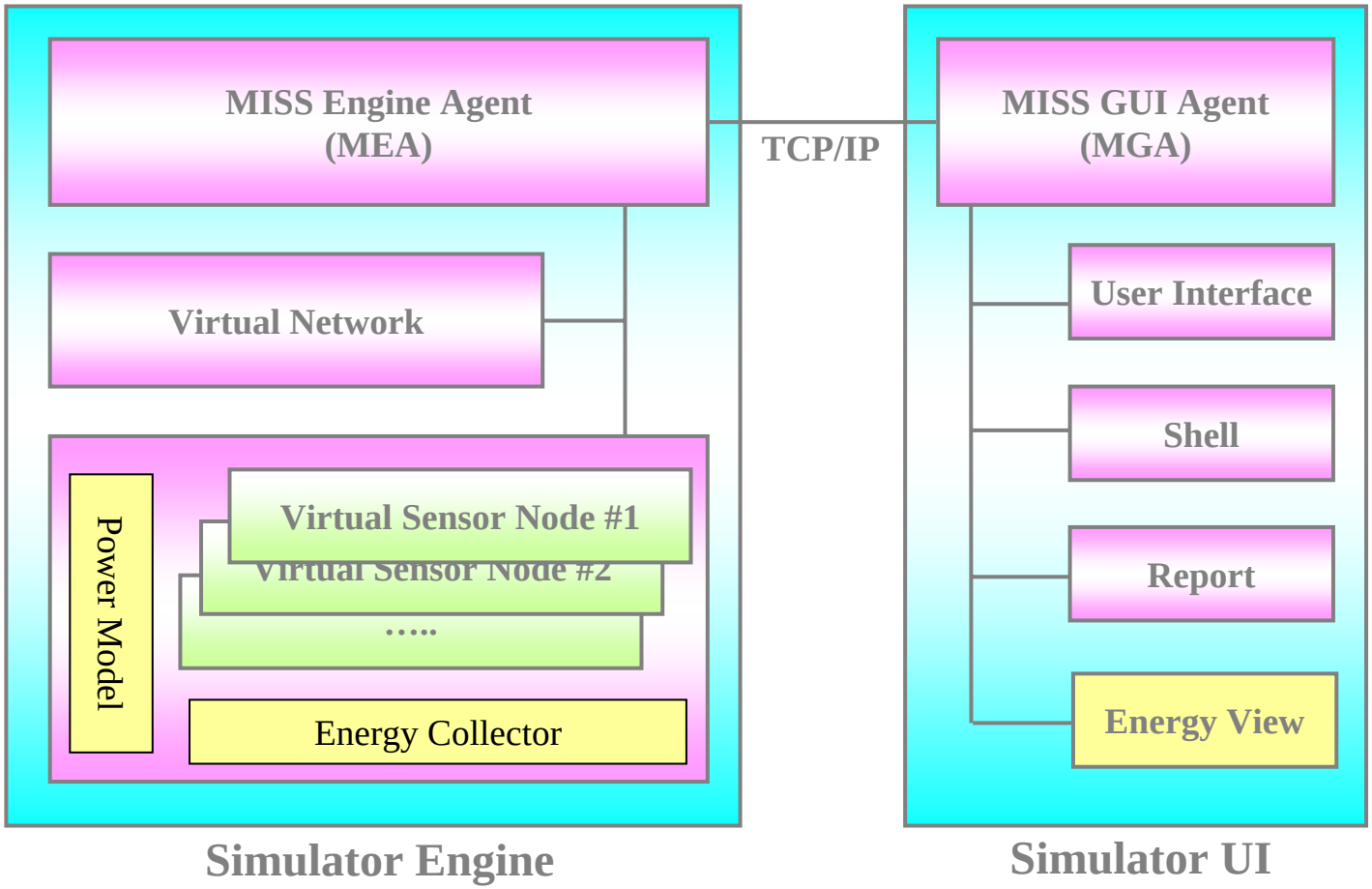


시뮬레이션 환경 (Nano OS)

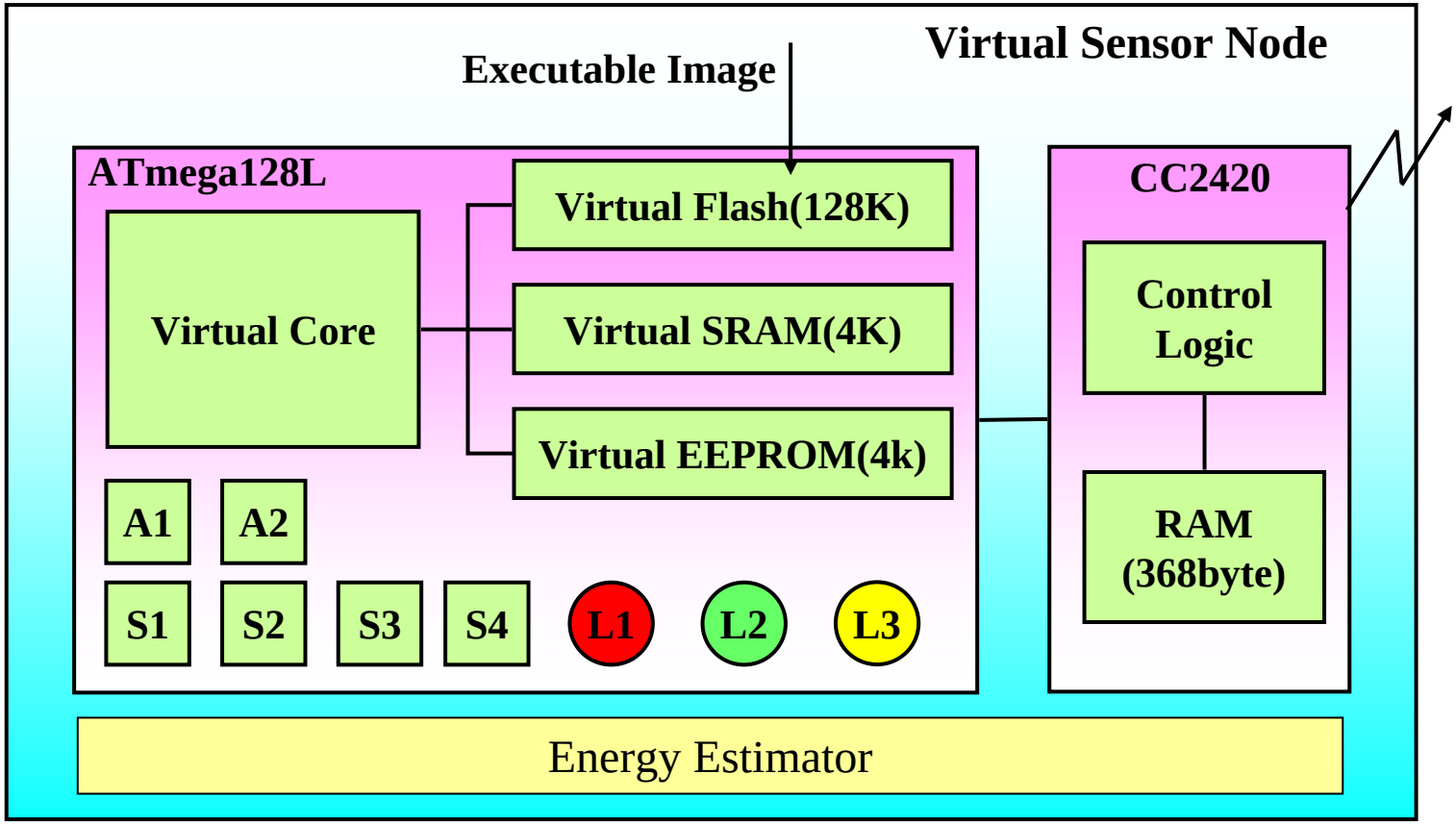
- Nano Qplus
  - 한국전자통신연구원(ETRI)에서 개발
  - 나노형 임베디드 운영체제
  - 센서 및 actuator의 종류에 따라 OS 커널을 최적화하여 재구성 가능한 scalable OS(TinyOS 보다 향상된 S/W architecture 지원)
  - 다양한 스케줄러 및 무선 통신(433, 868/916MHz, 2.4GHz, ...) 지원
  - 표준형 및 마이크로 임베디드 OS와 동일한 API subset 지원(POSIX 표준 기반)

- TinyOS
  - U.C.Berkeley 대학 중심의 NEST(Network Embedded Software Technology) 프로젝트에서 개발한 센서 네트워크 노드용 OS
  - 작은 크기의 OS (4KB 미만의 실행 이미지)
  - NesC 언어에 의하여 제공되는 컴포넌트 기반의 프로그래밍 모델로 구성
  - 모든 하드웨어 자원은 컴포넌트 형태로 추상화
  - 노드 간의 통신은 AM(Active Message)에 의하여 패킷 추상화

시뮬레이터 구조

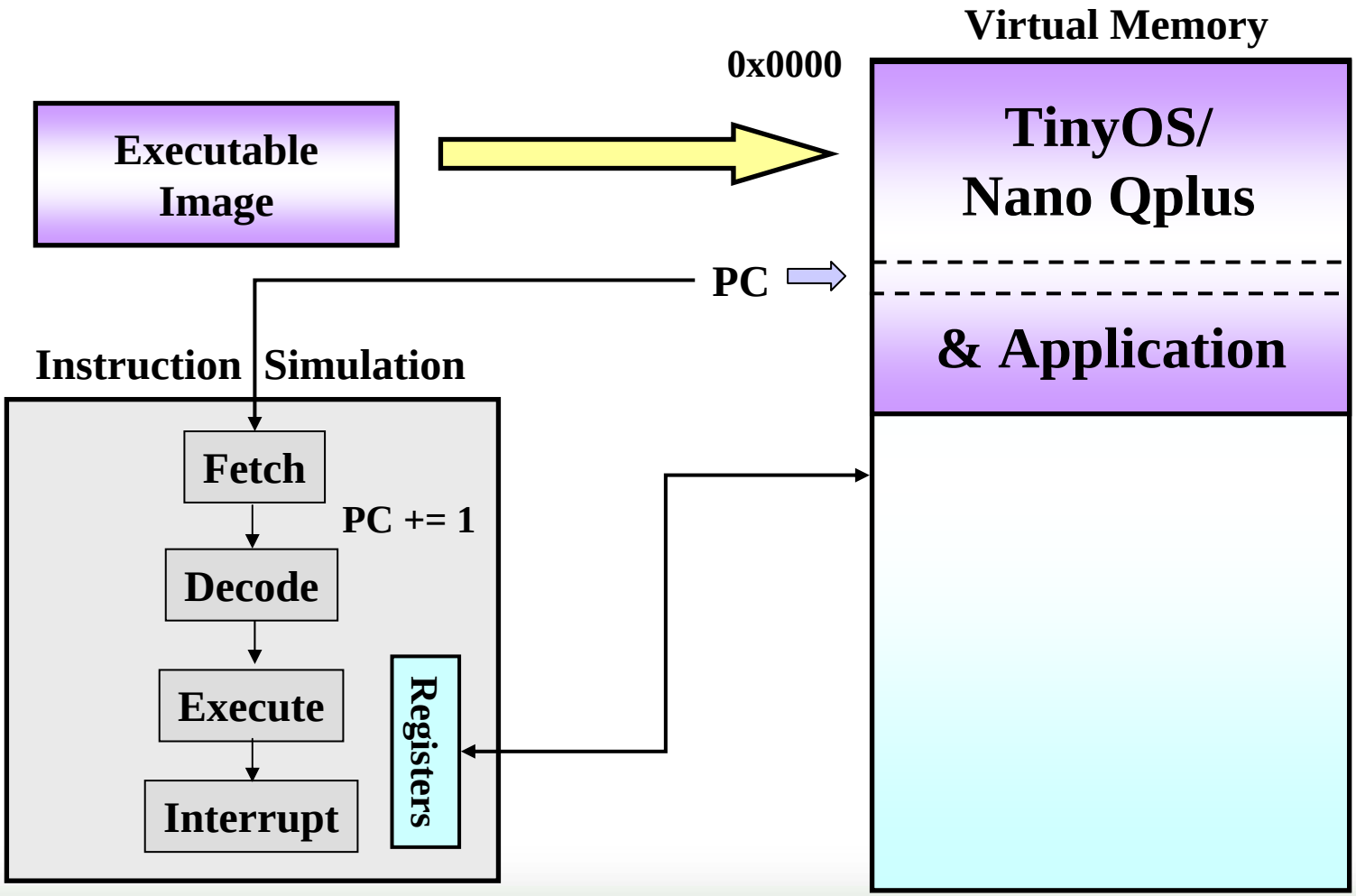

MISS Engine Agent
(MEA)
Virtual Network
Power Model
Virtual Sensor Node #1
Virtual Sensor Node #2
.....
Energy Collector
Simulator Engine
TCP/IP
MISS GUI Agent
(MGA)
User Interface
Shell
Report
Energy View
Simulator UI

가상 센서 노드 구조

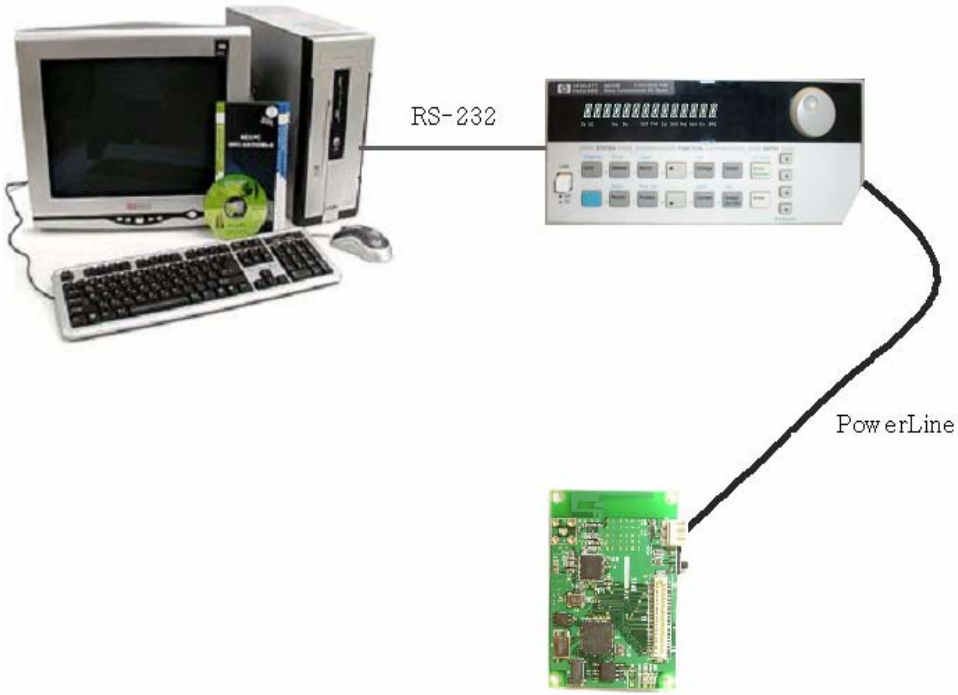


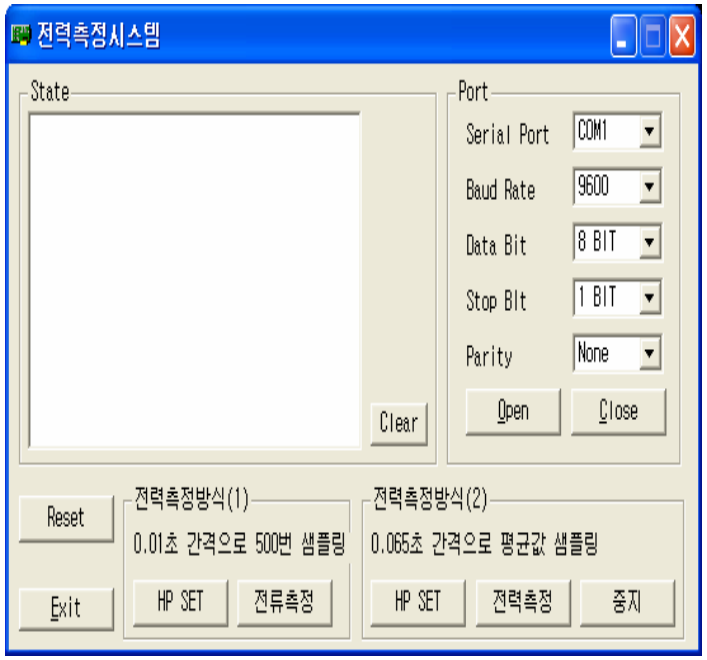
- S1, S2, S3, S4 : Virtual Sensor
- A1, A2 : Actuator
- L1, L2, L3 : LED

기계 명령어-레벨 시뮬레이션



전력 소모량 측정



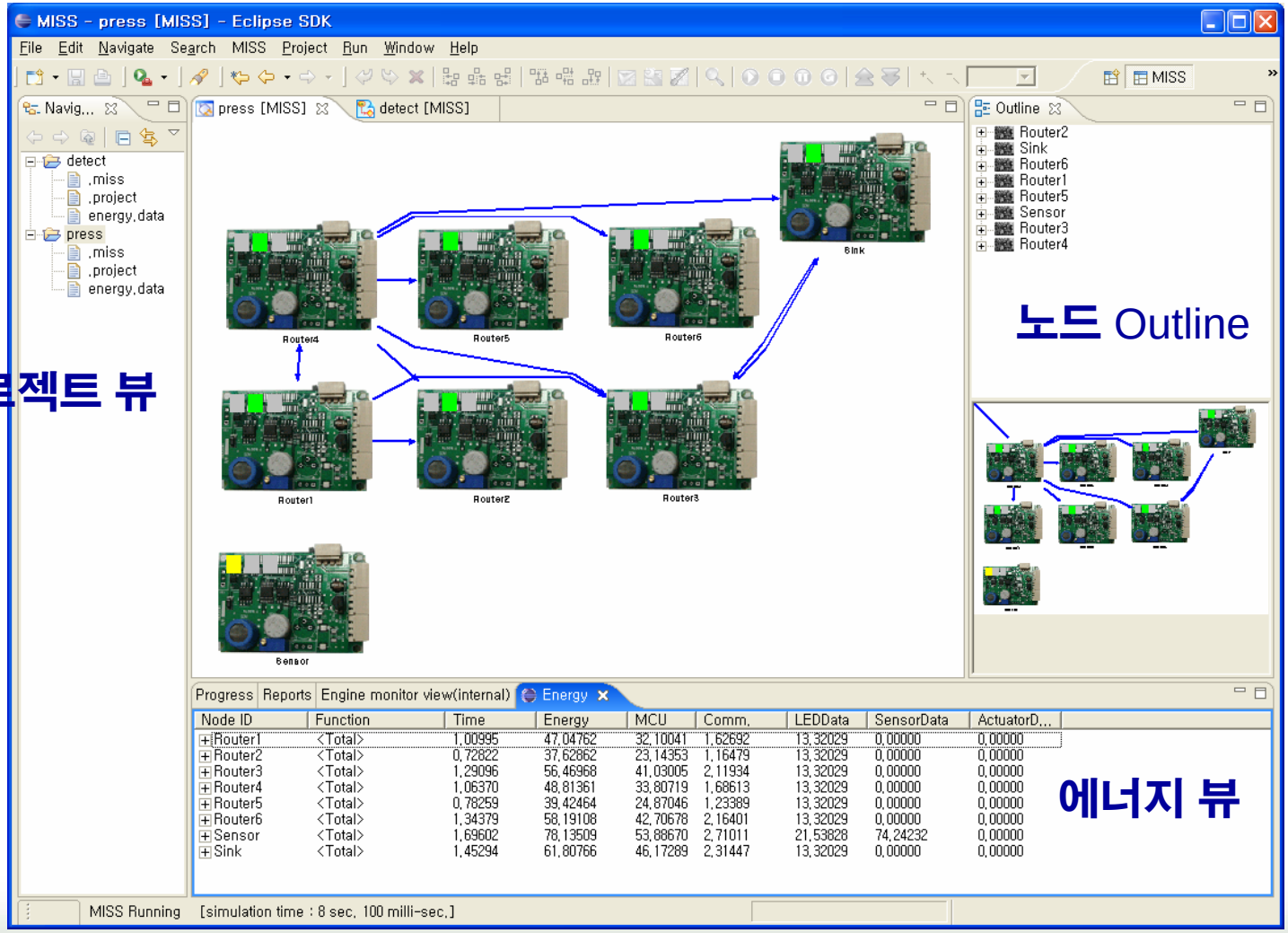


- 전원 공급기를 전력 측정 시스템 프로그램으로 제어하여 원하는 샘플링 간격으로 데이터를 얻음 (전류 최대 샘플링 간격: 15.6 us)
- 측정된 실측 데이터를 기반으로 전력 소모량 분석 모델 개발

센서 네트워크 사용 예

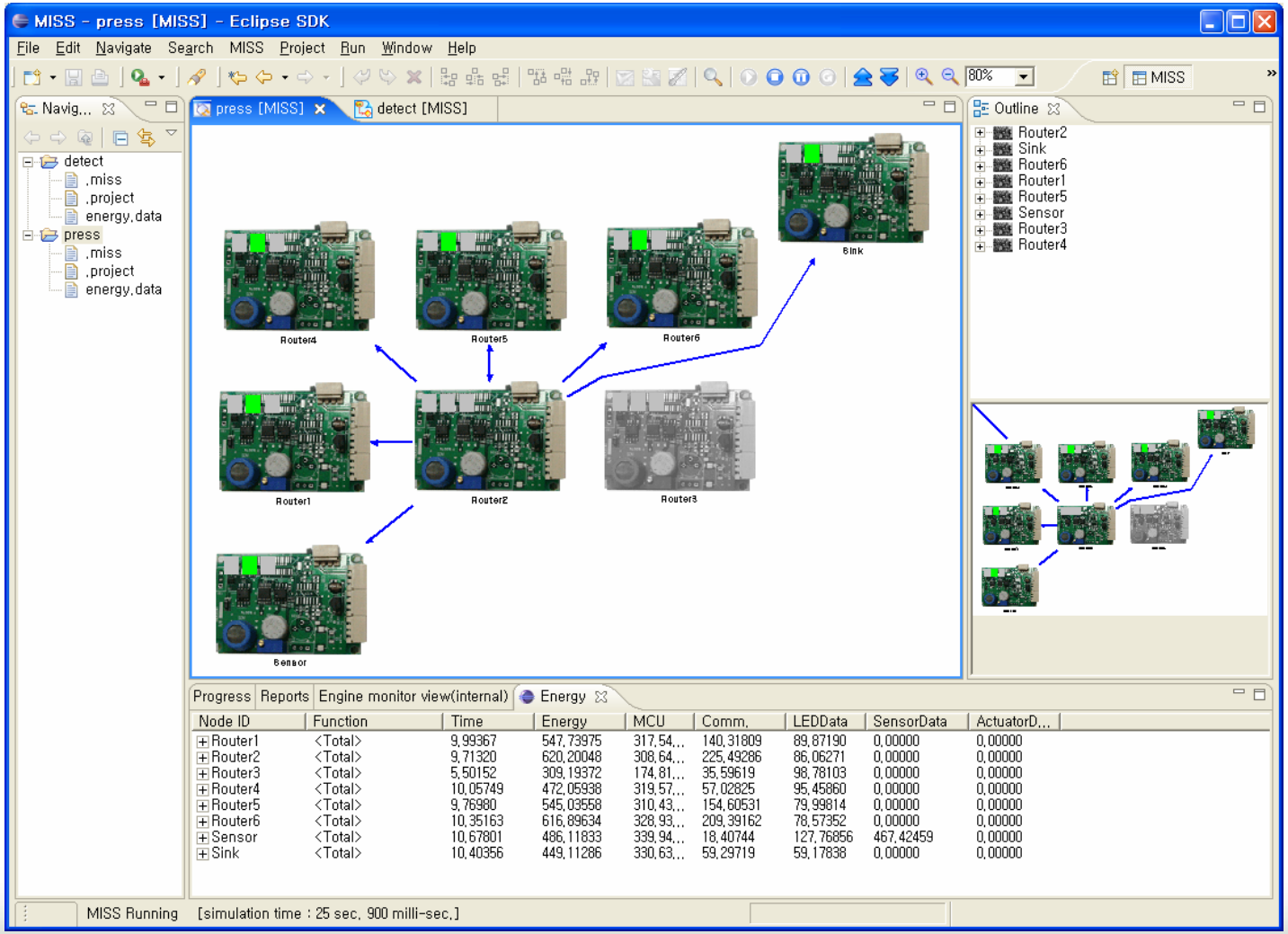

센서 네트워크 기반 자동차 부품 생산관리 시스템
라우터 노드4
라우터 노드5
라우터 노드6
싱크 노드
라우터 노드1
라우터 노드2
라우터 노드3
ERP
센서모니터링
시스템
프레스기기
프레스기기
B금형센서
D금형센서

시뮬레이션 화면



Node ID	Function	Time	Energy	MCU	Comm.	LEDData	SensorData	ActuatorD...
Router1	<Total>	1,00995	47,04762	32,10041	1,62692	13,32029	0,00000	0,00000
Router2	<Total>	0,72822	37,62862	23,14353	1,16479	13,32029	0,00000	0,00000
Router3	<Total>	1,29096	56,46968	41,03005	2,11934	13,32029	0,00000	0,00000
Router4	<Total>	1,06370	48,81361	33,80719	1,68613	13,32029	0,00000	0,00000
Router5	<Total>	0,78259	39,42464	24,87046	1,23389	13,32029	0,00000	0,00000
Router6	<Total>	1,34379	58,19108	42,70678	2,16401	13,32029	0,00000	0,00000
Sensor	<Total>	1,69602	78,13509	53,88670	2,71011	21,53828	74,24232	0,00000
Sink	<Total>	1,45294	61,80766	46,17289	2,31447	13,32029	0,00000	0,00000

시뮬레이션 화면 (node fault)



Node ID	Function	Time	Energy	MCU	Comm.	LEDData	SensorData	ActuatorD...
Router1	<Total>	9,99367	547,73975	317,54...	140,31809	89,87190	0,00000	0,00000
Router2	<Total>	9,71320	620,20048	308,64...	225,49286	86,06271	0,00000	0,00000
Router3	<Total>	5,50152	309,19372	174,81...	35,59619	98,78103	0,00000	0,00000
Router4	<Total>	10,05749	472,05938	319,57...	57,02825	95,45860	0,00000	0,00000
Router5	<Total>	9,76980	545,03558	310,43...	154,60531	79,99814	0,00000	0,00000
Router6	<Total>	10,35163	616,89634	328,93...	209,39162	78,57352	0,00000	0,00000
Sensor	<Total>	10,67801	486,11833	339,94...	18,40744	127,76856	467,42459	0,00000
Sink	<Total>	10,40356	449,11286	330,63...	59,29719	59,17838	0,00000	0,00000

마치며

- 향후 개발 내용
  - MCC (Mobile Convergence Computing)를 위한 Esto 기술 개발
    - DVS (Dynamic Voltage Scaling) 지원 최적화 및 분석 도구 기술
    - QoS 분석 도구 기술
    - Multi-Core 디버깅 기술
    - 원격 업그레이드 도구 기술
    - 타겟 CPU 독립적인 크로스 컴파일 기술
  - 디바이스 드라이버 개발 도구 확장
  - 8051 용 Nano Esto 개발
  - Qplus/Esto 상용화 및 보급 확산

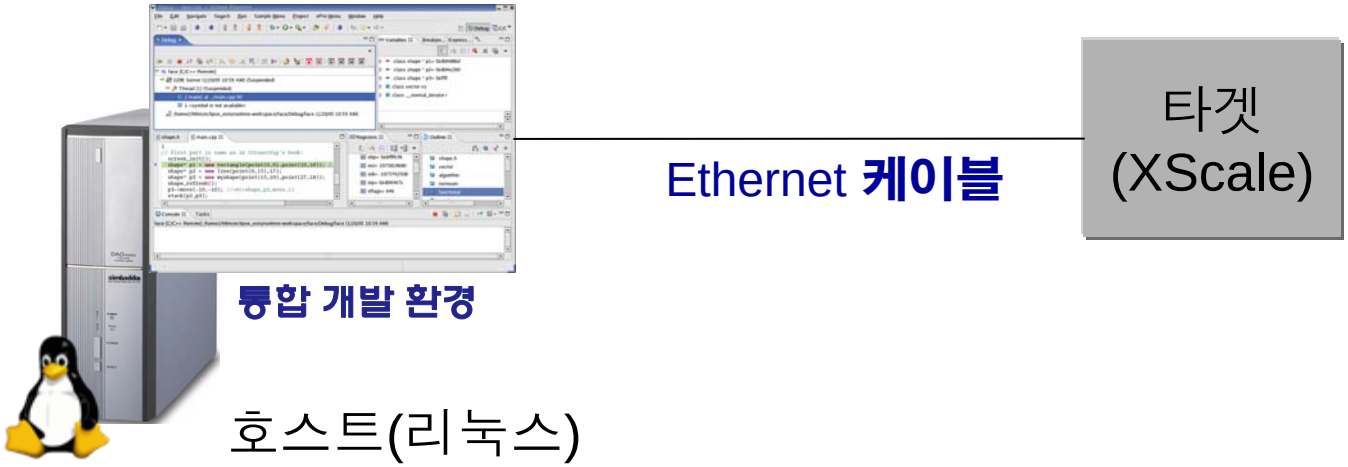
- Available in http://qplus.or.kr
  - Esto, Qplus, Nano Qplus evaluation 버전

- 시연

Esto 시연

❖ 시연 예제 : GTK 기반 GUI 응용 프로그램

1. UI 수정 및 소스 코드 생성 (GUI 빌더)
2. 수정된 소스 코드에 대한 크로스 컴파일 (IDE)
3. 프로그램 정지 및 변수 값, 메모리 값 확인 및 수정 (원격 디버거)
4. 루프 최적화 및 성능 분석 (최적화-분석 도구)



Nano Esto 시연

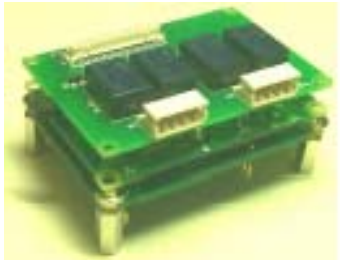
❖ 시연 예제 : 센서의 LED를 제어하는 Blink 예제

1. Blink 예제가 필요로 하는 커널 설정 및 빌드 (타겟 빌더)
2. Blink 프로젝트 빌드 및 시뮬레이터와 연동하여 수행 (IDE, 시뮬레이터)
3. 센서 네트워크 시뮬레이션 (시뮬레이터)

호스트 (윈도우)

ISP 어댑터

JTAG 어댑터



타겟 센서 노드