The Path Not Taken: Maximizing the ROI of Increased Decision Coverage

Laura Bright
McAfee

Introduction

- Decision coverage is popular metric for many teams
  - High coverage as an indicator of product quality
  - Many QA teams set a min-ship target
- But what does high coverage really mean in terms of quality?
  - Clearly it is good to cover as many decisions as reasonably possible
  - Some new tests have higher ROI than others
- If your numbers are above target, does that mean you have high quality?
- If your numbers are below target, is that a cause for concern?

Goals

- Reframe the question:
  - Instead of asking “What should we do to improve our code coverage numbers?”, ask “What areas of the code need increased coverage to improve the quality of our software?”
- Goal is not just to increase coverage, but to cover overlooked test cases and other reasonable test scenarios
- Some uncovered decisions have a low ROI
- Focus on overall quality rather than reaching a target number

Benefits

- Identifying automated functional test cases that were overlooked by QA
- Removing dead or obsolete code
- Finding product defects that cause some code to not get executed
- Identifying manual test cases to cover parts of code that are difficult to test through automation
- Determining areas of the code that would benefit from increased unit testing
- Identifying refactoring opportunities

Presentation Overview

- Background and Terminology
- Project Overview
- Examples
- Results

Background and Terminology

- **Line coverage** – percentage of lines of code executed
- **Function coverage** – percentage of functions executed.
- **Decision coverage (a.k.a. Branch coverage)** – percentage of all branches executed in conditional statements (for example, for a single "if" statement, have tests been executed where the entire statement evaluates to both true and false)
- **Condition coverage** – percentage of conditions that have evaluated to both true and false. This is different from decision coverage because a single "if" statement may consist of multiple conditions

  e.g. `if (a > b || c > d)`
- **Condition/decision coverage** – This is the union of the condition coverage and decision coverage. It has the advantage of simplicity without the individual limitations of each of these two metrics [Bullseye].
- Our team's focus was **condition/decision** coverage

Previous Work

- Marick (PNSQC 1991)
  - Case study of achieving different coverage goals through unit testing
  - Better to achieve high coverage through black-box tests and fill in gaps with unit tests
- Marick 1999
  - Coverage goal should be a guide for improvement, not a min-ship requirement
- Manu et al. (PNSQC 2010)
  - Case study on increasing block coverage from 91% to 100%

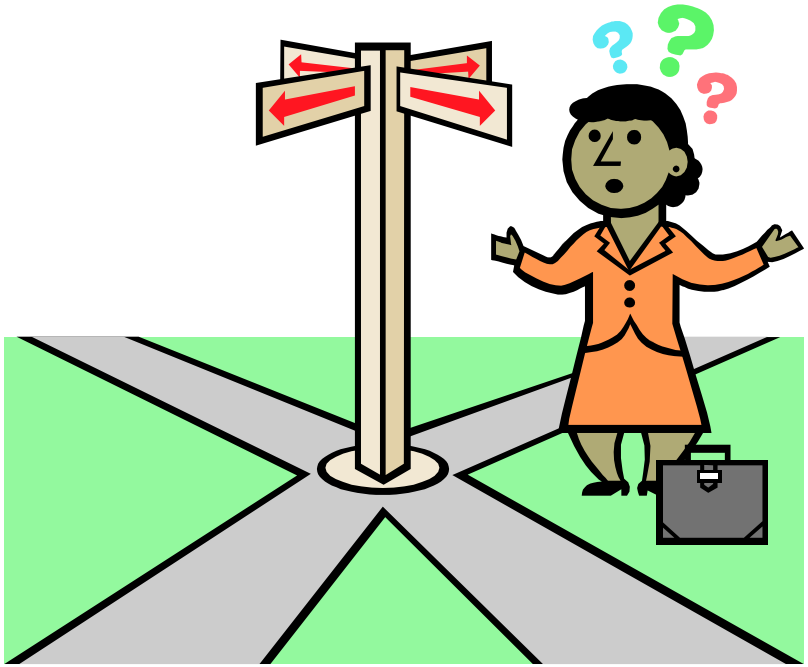
Project Overview

- McAfee Endpoint Security
  - Multiple components to protect systems for small and medium businesses
  - Mix of legacy and new code
- Multiple scrum teams distributed across sites in US and India
- C++ code uses Bullseye code coverage tool to measure coverage
- All teams report condition/decision coverage at end of each sprint

Efforts to improve coverage

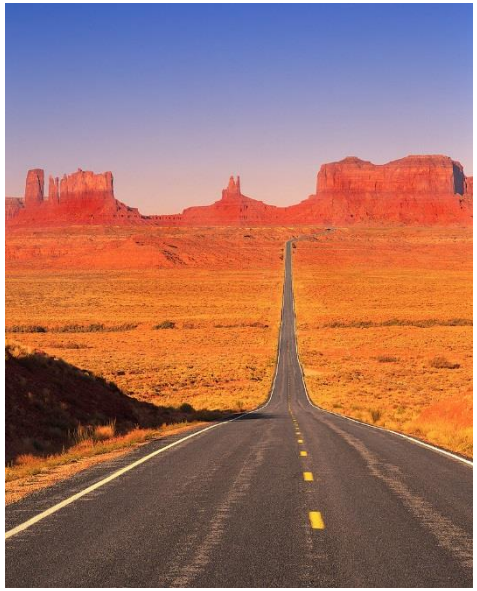
- Team meetings to review coverage data and identify areas that require additional testing
  - Entire team (all Dev and QA) attends
  - Aim for one meeting per sprint
    - One component per meeting
    - Limit meeting time to one hour
- For uncovered conditions/decisions - moderator identifies action required and assigns follow up tasks, for example:
  - Determine if function X is still called anywhere in the code
  - Write test cases and automation scripts to cover condition Y
  - Remove a block of obsolete code

Examples



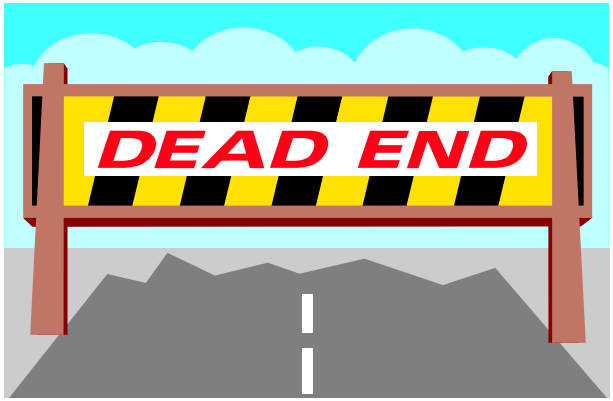
Uncovered functions

- Low hanging fruit
- Most fell into the following categories:
  - **Additional test cases needed** – Typically these were overlooked test cases that covered less commonly used product functionality
  - **Wrapper functions** – multiple APIs for the same functionality. Most are low priority.
  - **Dead code** – obsolete API's or functionality removed from product
  - **Functions that were expected to be covered** – required additional investigation, may indicate a product defect



Dead code

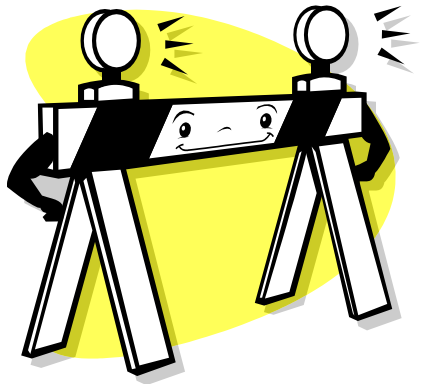
- Code blocks that were unreachable in practice
- Some could technically be covered by unit tests, but never would be covered by end user
- Features not scoped for current release
  - Functionality permanently dropped from product
  - “Placeholders” for functionality scoped for a future release
- Removing or commenting out this code can improve metrics and allow us to focus on testing supported functionality



Boundary tests

- Values that are outside of the acceptable range
- Usually straightforward to cover through black box or unit tests.

```
➔  T  if
   t (x >= MIN_VALUE &&
   t                 x <= MAX_VALUE) {
                     //do something
      }
   else {
                     // handle the invalid value
      }
```



Error Handling

- Error and null pointer checks are common in many projects
- Good practice to check return values
- Static analysis tools report unchecked values as defects
- Some of these are legitimate error conditions that need to be covered (Example 2)
- Others should never happen unless there is a bug in the code (Example 1)
- If the error should never happen, adding a test to explicitly cover it probably has a low ROI

Example 1

```
void importantFunction() {

        int errorCode = DoSomethingImportant();

   T if (errorCode == SUCCESS) {
           // <continue execution here>
        }
     else {
           // this should not happen
             Log_Debug("DoSomethingImportant() failed");
        }
        return;
}
```

Example 2

```
void anotherFunction() {

        int errorCode = DoSomethingElse();

   T if (errorCode == SUCCESS) {
           // <continue execution here>
        }
     else {
           Log_Event("a serious error occurred");
           ErrorRecoveryFunction();
        }
}
```

Null Pointer Checks

- Good practice to check that a pointer is not null before dereferencing it
- Memory allocation will normally succeed (testing with low memory is a valid test scenario, but low ROI to explicitly testing all of these conditions)
- Cleanup functions should free memory only if it exists, but explicitly testing both cases is low priority
- Explicitly testing the “false” condition for all of these conditions everywhere in the code is a low priority

```
        int * integer_array;
        integer_array = new int[MAX_ARRAY_SIZE];

➔   T if (integer_array) {
                        // <continue execution here>
        }
```

```
void cleanUp (Object * obj) {

   T if (obj) {
                delete obj;
        }
}
```

Results

- Our reviews indicated that most uncovered conditions/decisions were error and null pointer checks with low ROI
- We identified dead functions/code and new automated/manual test cases
- Much of this code was legacy code – difficult to unit test
- Increased overall coverage for the components to >50%

	Percent condition/ decision coverage before review	Percent condition/ decision coverage after review	Test cases added	Unreachable conditions/ decisions removed	Defects filed	Additional conditions/ decisions covered
Component 1	46	53	25	121	2	114
Component 2	48	50	20	~20	2	~25

Conclusions

- Need to consider how high coverage translates to high quality
- Your mileage may vary
  - These examples may not apply to your code base
  - But review process can help you maximize ROI of increased testing
- Consider the following:
  - Is this uncovered condition a valid test case?
  - Is it straightforward to cover this condition by a manual test, or by an automated functional or unit test?
  - Is there a good chance this condition will be covered in practice by an end user?
  - Is it a high risk if we don't test this condition?
- If you answer "Yes" to these questions, there is a high ROI to adding test cases for the condition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